Instruments

HE MAGAZINE of MEASUREMENT and CONTROL

Vol. 22 | MARCH 1949 | No. 3

cluding the JOURNAL of the Instrument Society of America

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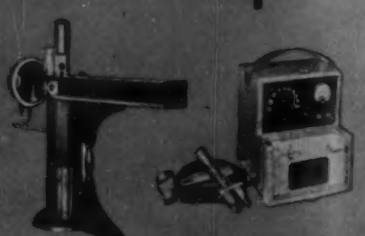

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Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

AIEE's Award *of* Edison Medal *to* Leeds: Latest Homage *to* Instrumentation

ON February 2 the American Institute of Electrical Engineers awarded the 1948 Edison Medal to Dr. Morris Evans Leeds "FOR HIS CONTRIBUTIONS TO INDUSTRY THROUGH DEVELOPMENT AND PRODUCTION OF ELECTRICAL PRECISION MEASURING DEVICES AND CONTROLS." His inspiring acceptance address, "The Growth of an Industry," is being used by *Instruments* as this month's Guest Editorial by courtesy of the AIEE (reprinted from *Electrical Engineering*). Equally appropriately, instead of introducing your "Guest Editor" in our own words, we yield the floor to L&N's Vice President and Director of Research Dr. Stein, himself an eminent Instrumentician. —MFB

Achievements of the Medalist

Substance of address by I. MELVILLE STEIN, Fellow AIEE, at the General Session, February 2, 1949

THOSE who, like myself, have spent all, or nearly all, of their professional lives in the fields of measurement and control, will share my feeling of pleasure in the realization that the Edison Medal has been awarded this year for meritorious achievement in those fields. A number of our Edison Medalists have made real contributions to these arts, but in no former case has the citation included a reference to them.

Our medalist, after having been graduated from Haverford College in Pennsylvania, spent several years teaching science. It happened to be the science of biology. He then made a careful appraisal of himself and, for reasons I never have been able to understand, decided that he was not cut out to be a teacher. Thereupon, he shifted his interests to the field of scientific instruments. I shall be able to mention only a few of his outstanding accomplishments, but these I believe to be typical, and I think you will agree that they establish our medalist as a great teacher, albeit not one of the classroom type.

As the first attribute of a good teacher, he always has been a thorough student; reading, consulting, and traveling at home and abroad to obtain full, and often first-hand, knowledge of what had been done in the field in which he happened to be interested at the moment. Shortly after having decided to make scientific instruments his life work, he enrolled at the University of Berlin to enlarge his knowledge of mathematics and physics. As most of you know, our medalist is a Quaker, and he has been a thorough student of Quaker business ethics as put into practice, particularly in England, by outstanding Quaker industrialists such as Rowntree and Cadbury. Because of its outstanding position in the scientific instrument industry, he studied particularly the philosophy of Doctor Ernst Abbe as applied to human relations in the great Zeisswerke at Jena. The demonstration that such principles and philosophies could be applied successfully in a different type of business and in a different country was, in itself, quite an achievement, and the particular arrangements and procedures adopted constituted real pioneering.

Perhaps the first thing that our medalist taught was that the manufacture of scientific instruments could be established successfully in the United States, fifty years ago, in competition with the then well established and highly respected organizations abroad.

It was at about the turn of the century that our medalist started manufacturing scientific instruments. About a decade later, when research departments hardly had had an opportunity to prove their real value, even in very large companies, our medalist established a separate research department in his very small company. He set up a system of research accounting to judge the merits of research in a small company. He had the courage to invest in research about 12 percent of gross sales receipts. In 1919 he made a plea for "Industrial Research in Small Establishments" and presented data to show that it could be done successfully (*Science*, Vol. 50, 1919, pages 445-8).

Then, he demonstrated that elaborate but sound measuring methods, well established in laboratories, were the only dependable ones in certain industrial process measurements. The criticisms of his early attempts bordered on ridicule, but Leeds had concluded that inasmuch as nature had made the forces to be measured very minute, it was up to the instrument designer to use methods and apparatus that could deal reliably with these very small forces. He reasoned that it was far better to use a multiplicity of parts in an instrument, each so lightly burdened that it had almost no chance of failure, than to use a few parts, each of which had almost no chance of success. His teachings in that direction now are followed almost universally.

It quickly became apparent that these machine-like industrial measuring instruments, which he developed, could be equipped with auxiliary devices to provide automatic control of industrial processes. To suggestions from within and without his organization that these instruments be equipped with simple "on-and-off" electric contacts to provide automatic control, Leeds was very cool. He already had given considerable thought to automatic control because his industrial recording instruments involved in themselves some rather refined automatic-control problems. He was satisfied that simple "on-and-off" control could not be expected to give good results in more than a few rather elementary applications. For the more difficult industrial control applications, he was convinced that unless an automatic-control device took into account all of the factors, the weightings and the timings that a good operator did, it would not be successful; but he was convinced also that an automatic-control device that *did* take into account all of these things could do a better job than the best operator could do. His visualization of sound automatic control was reduced to mathematical formulas and to experimental apparatus design at the time he applied for his pioneer automatic control patent in 1917.* These principles form the basis

ERRATUM.—In last month's editorial, third paragraph, the first line (instead of duplicating the fourth line) should read:

"It has a lot to do with THE MEN who conceive, invent, design, . . ."

*U.S. Patent 1,332,182, filed Aug. 2, 1917, issued Feb. 24, 1920.

for all refined automatic control today. In the more than 30 years since Leeds applied for his patent, further improvements have been made in automatic controls, but these improvements have come from adding factors and functions rather than by omitting any that Leeds considered essential.

In a similar manner, when he took steps to establish his enterprise on an enduring basis, as free as possible from the pitfalls of absentee ownership, he found weakness in ordinary corporate structure and weakness in partnership arrangement; but by superimposing a voting trust arrangement on top of a corporate structure he sought to gain the advantages of both and minimize the weaknesses of each. This involved a complex deed of trust for determining voting rights, share values, and similar matters, but Leeds did not let the complexities involved stand in the way of introducing the elements necessary to give the controls desired.

Likewise, in setting up an employee representation plan more than a quarter of a century ago, which was to deal, among other things, with wages, hours, working conditions, unemployment insurance, profit sharing, and many similar features, he did not shy away from the multiplicity of committees and procedures essential to accomplishing the intended purpose. The success of the plan may be judged in part by the fact that it won the *Forbes Magazine* prize in competition with a number of outstanding employee representation plans in effect in a number of progressive companies. And all of this happened long before the "New Deal" burst upon us.

Lest you get the impression that our medalist has an aversion to simplicity and an obsession for complexity, I hasten to assure that such is not the case. Actually, the Leeds characteristic procedure of including all of the elements and steps essential to reliable operation puts an added premium on the elimination of nonessentials, because the elimination of a nonessential element, or step, permits the addition of a new and useful one without adding to the complexity as a whole.

HONORS

Leeds' interest in education has led to his appointment to the boards of many educational institutions. For 17 years he served as president of the board of managers of Haverford College, and for 10 years he was president of the Board of Public Education in Philadelphia. He has been honored by the Brooklyn Polytechnic Institute with the degree of doctor of engineering and by Haverford College with the degree of doctor of laws.

The Edward Longstreth Medal of Merit of the Franklin Institute was awarded him in 1920 for his invention of the Leeds & Northrup mechanical recorder. In 1946 the American Society of Mechanical Engineers awarded him the ASME Medal "for outstanding achievements in the invention and development of electrical- and temperature-measuring instruments and in the field of industrial relations."

For his activities in the field of management he received the Henry Laurence Gantt Medal from the Institute of Management in 1936, "for distinguished achievement in industrial management as a service to the community." In 1946 he received the first Rotary Award of the Rotary Club of Philadelphia "in recognition of outstanding accomplishments in his consistent application of the principles of good will and brotherhood, in business, education, industrial management and world citizenship."

Finally, I should like to mention just two personal characteristics of our medalist. The first is his characteristic of analyzing very carefully mistakes and failures, the relatively few of his own, and those of others he has had the opportunity to observe closely. These mistakes he has memorized in intimate detail, and has turned them to advantage in later plans and activities. Those who shared my good fortune of having worked directly with Edison will recall how reluctant he was to abandon an incompleted experiment even after it was clear that the result would spell failure at the moment. He preferred to complete the experiment and carefully record and analyze the results, so that years later he could turn the failure to advantage in some other effort. The other personal characteristic of Leeds' that I wish to mention is willingness, even anxiety, to learn from people in all walks of life, young people, rank and file workers, and those whose manner of thinking is quite different from his own. He has a great and sincere respect for ideas and opinions learned through such sources, but regardless of the sources of his information and advice, I never have known him to compromise with sound, basic principles, whether in the field of physical science, ethics, finance, or human relations.

The Growth of an Industry

Response by MORRIS E. LEEDS, Fellow AIEE

I CANNOT overemphasize my profound appreciation . . . Reviewing the names of the thirty-seven previous medalists . . . it is with wonder and gratitude that I take a place as a minor luminary in this galaxy of first-magnitude stars.

The citation accompanying the medal refers to electric and precision measuring devices and controls, and I must assume that this award is to a considerable extent a recognition of the part which measuring instruments of all kinds have played in the country's industrial growth. So it may be appropriate for me to review some of the high spots of the instrument industry's development as I have seen it during the last half century.

In Philadelphia the industry can trace its beginning to Benjamin Franklin and his time, but it was until comparatively recently very small. When I was serving my apprenticeship in the early 1890's, scientific instrument manufacture still was struggling for a foothold in the United States, and the shadow of Europe was over everything that we attempted. My work included the unpacking and checking of a great many European instruments. These so commanded my respect that, having decided on the instrument industry for my career, I . . . visited most of the prominent instrument makers from Glasgow and London to Geneva, Prague, and Vienna.

Kelvin and James White, the Cambridge Scientific Instrument Company, Nalder Brothers, Elliott Brothers, Carpentier, Otto Wolf, Siemens & Halske, Hartmann & Braun—just to mention a few—were great names in those days, and my visits to their establishments gave me a great respect for their ability as instrument makers. Those were the days when many college professors believed that they had to complete their education by work in Germany. They came back to America with the deep conviction—which was true barring a few noteworthy exceptions—that foreign instruments were better than those being made in this country, and the further conviction in many cases that they were better than any that could be made here.

Aside from the prejudice in favor of European apparatus, we were dependent on Europe for essential materials, including hard rubber, optical parts, galvanometer mirrors, and manganin in all its forms. We had to pay a duty on these materials when we imported them, at the same time that under the law then in effect educational institutions could import scientific apparatus free of duty; so the same materials coming in to them, but made up in instruments, were free of duty.

These handicaps against which the struggling beginner in instrument manufacture had to work 50 or 60 years ago gradually vanished during the early decades of this century. The privilege of duty-free importation was abolished. Prejudices in favor of foreign manufacturers were replaced gradually by reverse prejudices, particularly against Germany after the first World War. For a good many years now it has not been necessary to import any manufactured foreign materials; price, quality, and reliability of supply make it more satisfactory to purchase in this country. The Bureau of Standards was established as an independent institution and made it unnecessary to send instruments to the

Reichsanstalt, or any other foreign standardizing laboratory, to be certified.

In the earlier days the laboratories of educational institutions and of certain government departments were the industry's chief customers, except for such instruments as switchboard ammeters and voltmeters, pressure gages, and so forth, which already were beginning to be used extensively in power plants. But recorders scarcely had appeared, and controllers were not yet seriously considered. The telephone and telegraph industries were also among the earliest to use instruments extensively, which they did to measure insulation resistance, locate faults in long lines, and, gradually, for many other purposes. Like extensive use of instruments now has spread to many other industries.

IMPORTANCE OF ELECTRICAL MEASUREMENTS

The versatility of electrical measuring methods is largely responsible for this. Among the diverse physical and chemical measurements made electrically are temperature, strain, acidity, solution concentration, composition of gases, and automatic quantitative analysis of several elements in the same solution. Many of these are basically electrical measurements and not merely electric transmission of measurements made by other methods. For instance, electrical measurement of acidity, or pH, is a measure of the concentration of hydrogen ions, and this concentration is measured directly by electromotive force. In addition to the ability to measure quantities not generally considered electrical, electrical measurements have the advantages of utilizing tremendous amplification, of ready transmission over considerable distances and of automatic actuation to provide recording and control.

Electrical scientists and engineers may feel properly proud of the contributions made by electrical measurements to all technology and industry. Many of these contributions have been made by members of the Institute, which long has maintained an active technical committee on instruments and measurements. Admittedly, we owe much to fine optical and mechanical instruments such as the microscope, the spectrograph, the gyroscopic compass, and the venerable mechanical clock. On the other hand, we find the electron microscope opening new fields beyond the range of the optical microscope, and crystal oscillators providing time measurement and control beyond the abilities of the most precise mechanical clocks. In the field of spectrography, combinations of electrical elements with the usual optical elements are opening new frontiers.

As an indication of the manner in which electrical measurement and control have become essential parts of most continuous industrial processes, I may cite an example from the electric central station industry. Here electrical instrumentation plays a very important role in the control of load and frequency and does much to make practicable the tie-in between large electric distribution systems and, incidentally, to assure the frequency control that makes electric clocks so useful and popular.

As another indication of the important position now held by measurement and control, the United States alone now has three journals devoted to the many phases of those subjects.

In the forty years since the Edison Medal first was awarded, rule-of-thumb in industry has been replaced very largely by accurate measurement, and in the arts both of peace and of war in-

EIGHTY YEARS YOUNG ON MARCH 6

struments for measuring, recording, and controlling are to be found guiding and regulating many processes to insure efficiency, quality and quantity of output.

THE SOCIAL ASPECTS

A thoughtful person cannot contemplate the successful prodigality of all these industries which a review of instrument application brings to his attention, without at the same time noting with dismay the lamentable failure of our society to use the great resources which the industry provides to help insure a better social order and an increasing measure of peace and security, nationally and internationally. Fifty years ago we were in what Henry Seidel Canby has called the age of confidence. We confidently believed in the soundness of our institutions, and we fully expected that the progressive conquest of natural resources would enable us to fashion a healthier and happier social order. So it is indeed cause for dismay that our growing resources seem to diminish rather than increase our progress in these desirable directions.

Such reflections as these evidently have troubled the consciences of engineers, because there is much discussion of the engineer's responsibility for the social effects of these industrial successes to which his particular knowledge and skill have contributed so conspicuously. Meetings have been devoted to the subject and able papers have been presented. Out of it all there seems to be an emerging conceusus on engineering responsibility for the social order which may be summarized as follows:

It is society as a whole, rather than our engineers and scientists, which is responsible for the use that is made of our technical developments.

The engineering disciplines do not equip one with particular knowledge or skill that is likely to be useful in the social field.

But engineers do have an approach which is typically, though not uniquely, theirs, and which might well be employed much more thoroughly than it is in attacking social problems. These are the essentials of this approach: the definite formulation of the problem, the assembly of all pertinent information that is available and its analysis, and on this basis the formation of plans for dealing with the situation — all to be done within a limited, specified time.

Having acquired skill in the practice of this approach, the engineer does, it seems to me, have a moral responsibility as a citizen to make it useful in dealing with social problems when he has the opportunity. Although this is not the time to explore the avenues through which this approach may be applied, it may be said safely that economic planning is one of them, and I bring that in because I want to refer to a widespread experience in the precision instrument industry that possibly may carry over into that of economic planning. It often has happened in the instrument field that the use of measuring and recording devices to obtain pertinent information has shown the need for controlling devices. One would not be warranted in making the deduction that in the social field a more complete assembly of pertinent information would indicate a need for more controls, but he certainly would not be warranted in assuming that it would not. It is interesting to speculate whether the engineering approach, applied rigorously and without prejudice, would lead us to more or less government control of industry. Our analogy certainly would indicate that such controls might be difficult and complicated, and call for the exercise of much care in their application, but that if soundly applied where needed, their advantages would be conspicuous.

May I conclude this brief discussion of the engineer's social responsibility by quoting from a paper which I wrote some years ago?

> It is not the vast knowledge of the engineer nor the skills and techniques of the profession, useful as these may be, that put him in position to make a uniquely valuable contribution to the art of dealing with complex economic situations; but I believe he can make such a contribution by passing over into the field of economic practice his habitual way of looking at and dealing with problems, which leads him to see clearly what he wants to accomplish, to take into account systematically all the factors and circumstances which will influence results, and then plan so that the objective may be achieved as nearly as possible by the time wanted and under existing conditions.

The INVERSE DERIVATIVE—*A* New Mode *of* AUTOMATIC CONTROL

By C. B. MOORE, Moore Products Co., Philadelphia 24, Penna.

PURPOSE of this article is to introduce and to explain a new process-control function—designated "inverse derivative"—also to show the relationship of this new action to the recognized control functions: proportional, reset, and rate action (or "direct" derivative). Specific attention is given to the time-constants of the process and of the control means. Established functions, as embodied in force-balance systems, will be reviewed, in order to clarify their interrelationship.

Fig. 1 illustrates, diagrammatically, a circuit for controlling temperature, flow, liquid level, density, or other process variables which can be converted, by a pneumatic transmitter, to a proportionate pressure. The complete control circuit consists of a series connection in the following order:

(a) Process

(b) Means of measuring the process variable and of transmitting a proportionate air pressure.

(c) Air-operated controller

(d) Diaphragm-motor control valve with a positioner.

For optimum control results, *each* element in the control circuit must be friction-free. This requirement is important, because the friction of each element would be additive in its overall effect on the control. As shown in Fig. 1, friction of the pen on the chart, and of the various links and pivots in the receiver, cannot affect the control circuit. Control-point setting is merely a pressure which loads the controller: this eliminates frictional effects from the operation of the controller. It should be noted that both the process indicator (or recorder) and the control-point-setting means, are outside of this series circuit.

When it is advantageous to hold the time-constant of the control circuit to a low value, the controller should be located at the process. When this element of time is less important, the controller may be located in the control room—either combined integrally with the control-point-setting regulator, or mounted behind the panel, as a separate unit.

The various control functions—proportional, reset, and rate action—are often confused. It is the writer's belief that this confusion is caused by a general failure to visualize the interrelationship and simultaneous functioning of these control actions.

Fig. 2 has been prepared in an attempt to show all of these functions in one diagram. The ordinate represents full-scale process change, while the abscissa shows the full valve travel necessary to produce that change. The 45-degree line indicates that a 100 per cent change in process variable will cause a 100 percent change in valve travel. When the proportional band on the controller is set to give this result, this adjustment is known as a wide proportional band, or 100 percent throttling range. If the line has a zero slope, it represents a zero percent throttling range, or "on-off" control. With this adjustment, the slightest change in the process variable will stroke the valve from one limit to the other.

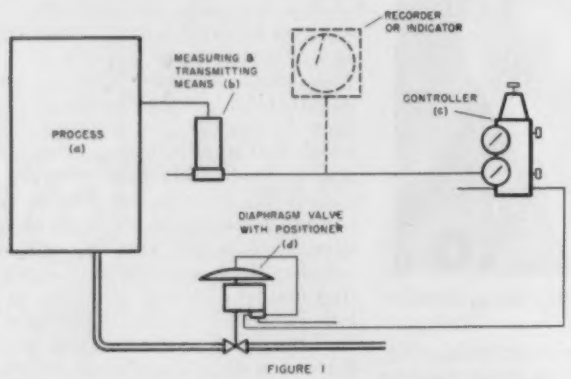


FIGURE 1

DIAGRAM OF TYPICAL PROCESS-CONTROL CIRCUIT

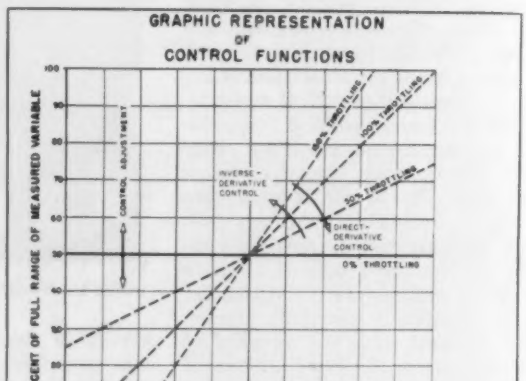


FIGURE 2

If the entire family of curves is moved either up or down, various control-point settings are represented. If the entire family of curves is moved either to the right or left, indicating a change in valve position with the process at the same value (the result of a load change), reset adjustment is represented. In the controller, this reset adjustment may be accomplished either manually or automatically.

With manual reset, the operator must watch the process and make adjustments in the valve position, after the process drifts from the control point because of load changes. In a force-balance system, adjustment would be made by use of a manually-loaded regulator.

If reset is automatic, a loading pressure is also used—but the pressure is adjusted automatically, according to the elapsed time and deviation of the process from the control point. The reset rate is the speed at which this automatic adjustment is made. (This rate should never be confused wth "rate action," which is a derivative-control function.)

Processes with long time-constants (in the order of one minute or more) require a so-called "anticipatory" control function, which avoids overshooting the control point and producing oscillations. This function is also known as "rate action," or "derivative response." If an operator were trying to hold the process at the control point, manually, and saw that the process variable was rapidly approaching the desired value, he would operate the valve "quickly" in the opposite direction, to anticipate the arrival of the process at the control point. On the other hand, if the process variable were changing "very slowly," in the right direction, the operator would make little or no change in the valve position. We can see, therefore, that the operator instinctively puts "rate action" in his manual handling of the valve. It is obvious that many processes are "touchy" to the degree where this action must be automatic in order to be effective. Hence the specific need for rate action as an automatic-control function.

The foregoing example shows that rate action recognizes only speed, that

throttling action recognizes deviation from the control point, and that reset action recognizes elapsed time and magnitude of the deviation. Reference to Fig. 2 shows that a temporary clockwise rotation of the family of curves about the process value, at the instant deviation takes place, is the same as rate action. In simple language, it can be said that rate action, or derivative response, is an automatic throttling-range adjustment which temporarily narrows the band, depends on speed only, and is independent of the control point.

After an understanding of the various established control functions, a study of the effect of friction on the over-all control performance is important. If there is friction anywhere in the circuit, the control valve cannot move until it has received a signal from the controller. This signal cannot be sent until the process has changed enough to overcome the friction of the measuring system.

In temperature control, a sudden change in load does not result in an immediate change in temperature. The temperature changes as an exponential or similar function, as illustrated in Fig. 3. If "A" represents the time a change started and "F" is the friction level or "dead-zone" of the circuit in terms of temperature (even though this may be a small fraction of one per cent of full range), then time "T" will have elapsed before the valve can start to respond. Therefore, the process has already been started on a swing, with the corrective means lagging behind. The resultant self-sustaining cycle has been projected on the graph.

If the system is essentially friction-free, the dead time will be a small value, such as "t," and the continuous cycle will be of negligible magnitude. It is axiomatic that to obtain optimum control, the entire measuring-and-control circuit must detect and respond to changes in the process variable the moment they start.

If the time-constant of the process is large, there will be a considerable lapse of time, after an upset, before this cycle damps out and the process holds to the control point. Such applications can be benefited materially by the addition of "rate action" or "direct derivative."

Fig. 4 was plotted from actual test results, obtained on a circular chart recorder. With a control point of 125 F., the load was suddenly decreased — so that, without control, the process would have changed eventually to 148 F. Even with a friction-free pneumatic transmission and control circuit, it took approximately two hours, and four cycles, to restore stability. The load was then increased suddenly, and the cycle was damped out again in slightly over one hour. This difference in time was probably caused by differences in valve characteristics at the positions required for the two load conditions. The throttling adjustment of 16 percent and the reset rate of 5 minutes per repeat remained the same under both tests.

Fig. 4 shows also the results of a test under the same conditions, except for the addition of a direct-derivative action which has a setting of 0.5 minutes. A comparison of the results of these two graphs shows conclusively that the process tested was materially benefited by the addition of a derivative function in the control action.

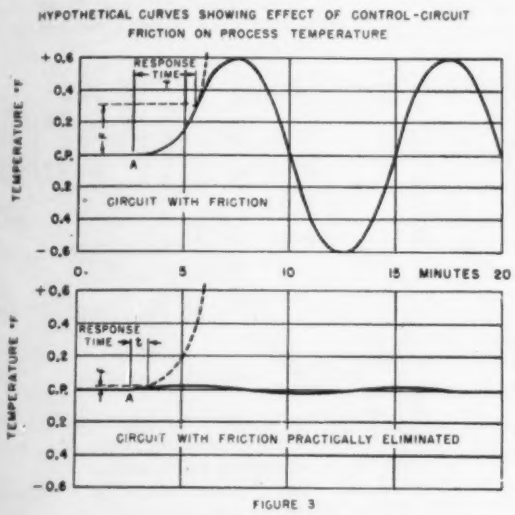


FIGURE 3

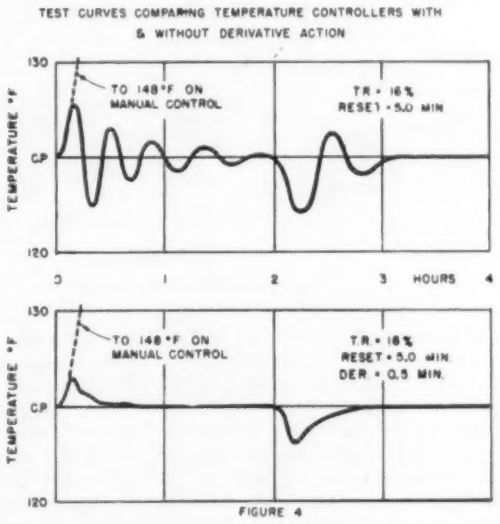


FIGURE 4

Fig. 5 illustrates diagrammatically the mechanical means, in a force-balance controller, of including process transmission, control-point setting, throttling, reset, and derivative. The instrument works on a balance of pressures to arrive at the correct controller output, which is also a pressure. The construction consists essentially of a simple stack of sections and diaphragms. The derivative unit (shown as a separate member, although it may be combined in the stack of the controller), superimposes its effect on the output of the controller. The booster

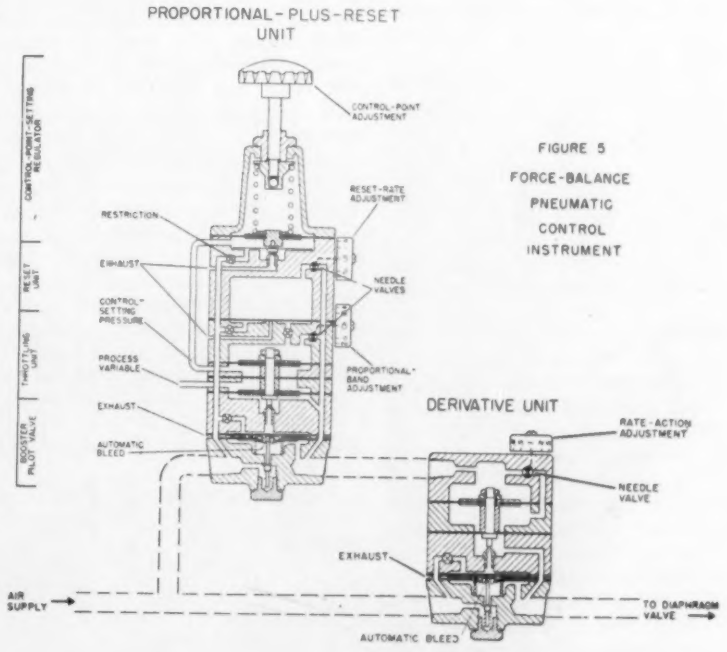


FIGURE 5
FORCE-BALANCE PNEUMATIC CONTROL INSTRUMENT

pilot, built into the derivative unit, serves to maintain a constant pilot-nozzle differential-pressure and to provide a large capacity for speed in transmitting air pressure to the valve.

On applications where it is desirable to locate the controller near the process, with the control-point adjustment in the central control room, the control-point

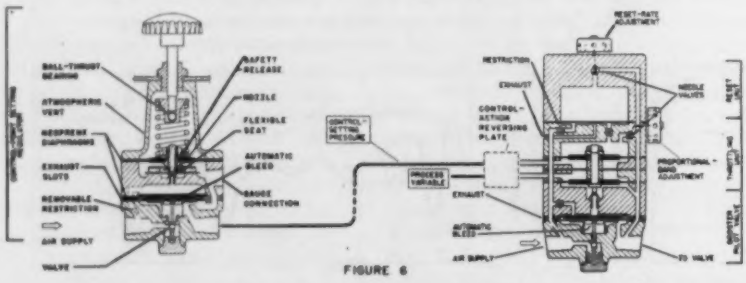


FIGURE 6

REMOTE-SET TYPE FORCE BALANCE CONTROLLER

loading is separated, as shown in Fig. 6. The control-point adjustment is a precision regulator, with a high-capacity pilot for long-distance transmission. A derivative unit may be added, and then the circuit becomes essentially the same as that shown in Fig. 5.

"Direct" derivative has been defined, for simplicity, as a means of temporarily narrowing the throttling range—dependent on speed of the process variable, and independent of the control point. It also leads the output of the controller—hence the term "anticipatory" control. The inverse of this function would be to widen the throttling range temporarily, and to lag the output of the controller. The "inverse-derivative" unit, shown in Fig. 7, is made by reversing both the diaphragm assembly and one section of the "direct-derivative" unit shown in Fig. 5.

The control of flow in industrial processes must be accomplished without introducing sustained oscillations or cycling of the process. One accepted method is simply to widen the throttling range (of a simple proportional-type controller) until stability is obtained under normal conditions — together with a margin of safety. On some applications, stability (complete absence of sustained oscillations) is not possible unless a throttling range of 500 to 600 percent —or even more—is used. With such a setting, the control of the process is lost for all practical purposes, unless there are no load changes.

Another common method of obtaining stability in flow-control applications is to restrict the response of the flow-rate measuring means—the differential gage or manometer. This restrictive action has an effect quite similar to that of widening the throttling range, with a resultant sacrifice of control. Because continuous cycling of the process cannot be tolerated, the use of either of these methods of damping becomes, at best, the lesser of two evils.

It is an interesting fact that once a flow-control process has become stable, it is possible to narrow the throttling range without throwing the process in-

to a cycle (provided the process conditions remain steady.) However, the instant there is the slightest process change, a sustained cycle will develop. This cycle will persist until the proportional band is widened, or until other damping action is introduced.

The inverse-derivative unit is designed to accomplish just this function —automatically. It permits the throttling range to be adjusted to less than 20 per cent of its normal value, and this setting is maintained just as long as the process is steady. The instant there is a process change, or any slight upset, the throttling range widens automatically, until conditions are again stable. Then it returns to the narrow range. Thus, the advantages, both of narrow throttling for good control and of wide throttling for stability, are obtained through the addition of the inverse-derivative function to the output of any pneumatic controller used on a process having a short time-lag (in the order of a few seconds or less).

Optimum process control requires getting back to the control point just as quickly as possible, after an upset or load change. Fig. 8 shows actual test results on liquid-flow control, in which the reset rate was set at 0.2 minutes and the throttling range was set at 50 percent, which was just wide enough to obtain stability. (A throttling range of 45 percent would have thrown the process into a sustained cycle.) A load change was made, equivalent to about 10 percent of full-scale range. The control acted to correct this upset, permitting a maximum change of about 6 percent, with complete recovery after the elapsed time shown. If spoilage was caused by a deviation from the control point, then the area under this curve represents the material lost—or the material which would at least have to be re-run.

Fig. 8 shows also test results of the same process, with the addition of the inverse-derivative function. The reset rate was maintained at the same value, and it was found that the throttling range could be lowered to 8 percent without losing stability. A reduction to 7 percent would have produced a sustained cycle. The improvement in control and increased speed of recovery is made apparent by comparison of these two graphs—both of which show similar results when the load conditions were reversed.

Inverse derivative should not be considered the cure-all for liquid-flow applications. There are many other conditions (such as valve size, location, and turbulence), which are too numerous to mention and which are beyond the scope of this article. There is, however, the very important factor of transmission time-lag, which is often overlooked. This oversight occurs because of the general knowledge that several seconds added to the time-constant of an ordinary temperature-control circuit have no sig-

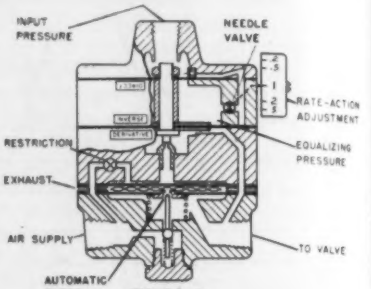


FIGURE 7

INVERSE-DERIVATIVE UNIT

nificant effect on the control result. This condition certainly does not exist in a flow-control application.

Tests were made to determine the effect of transmission lag on the minimum throttling ranges which were possible for stable control. These results are shown in Fig. 9. The total length of 3/16 inch I.D. tubing used in each test was double the transmission distance shown. (For instance, the values for a 600-foot distance between the process transmitter and the controller include the transmission lag in the return line, also 600 feet long, to the diaphragm valve.) Arbitrarily, stability was considered to be established, when, after a 15 percent permanent load change, the record showed an overshoot of approximately 1 percent of full scale on the return of the process to the control point. The improvement in permissible throttling-range setting with short transmission distances is quite apparent.

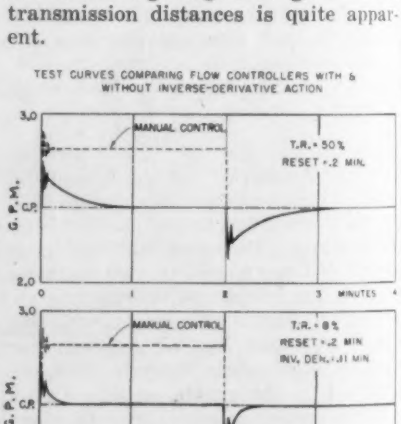


FIGURE 8

The tendency of a process to develop a "reset cycle" makes an interesting problem for study. Experience has shown that a fast reset rate used on temperature control will develop this cycle, while a flow-control application

will not develop it, if the control circuit has a fast response. In the tests shown in Fig. 9, a reset rate of 1 minute was necessary, because any shorter time would have resulted in a reset cycle when 600 feet of transmission were used. With a short transmission line, this time-constant could have been reduced to 0.04 minutes or less, without introducing any reset cycle. These data show that the loss in controllability with long transmission lines is even greater than that indicated by the graph.

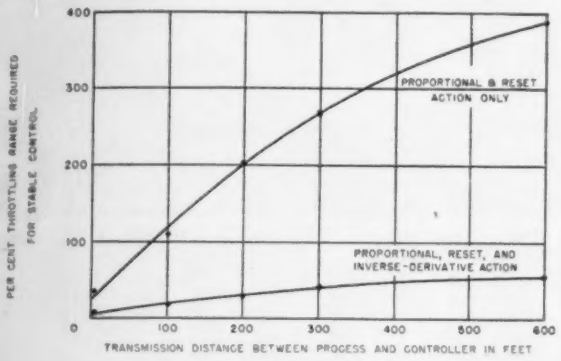


FIGURE 9
EFFECT OF TRANSMISSION DISTANCE ON THROTTLING RANGE (LIQUID-FLOW CONTROL)

The second curve, which shows the addition of the inverse-derivative function, indicates how much lower the throttling range may be set. The tests also demonstrated that the inverse-derivative unit decreased the time of recovery from a load upset, in a ratio varying between one-half and one-sixth of that required without the unit. When a slow reset rate was required for stability, this improvement was greater than with a fast reset rate. This improvement does not mean that the addition of inverse derivative is the cure for long transmission lines. Better control will always result from eliminating these lines with the use of a remote-loaded type of controller, located at the process. Further improvement in control will then result from adding the inverse-derivative unit. In reviewing the curves of Fig. 9, the reader must remember that the process is flow, which can change faster than the measuring-and-control system can respond.

There has been much discussion regarding the practical application of rate action, or derivative control, to industrial processes. There has also been a great deal of misunderstanding on the matter by the average instrument user. Fig. 10 shows hypothetical curves, which have been prepared in an attempt to clarify the relationship between various processes and the type of derivative action required.

In this graph, showing hypothetical values, it is assumed that the control-means time-constant is the same for temperature, liquid-level, pressure and flow-control processes. The temperature-control process will have the longest time-constant (usually much longer than that of the control means). Liquid-level, pressure, and flow process time-constants are also shown. Flow-control applications have a very short time-constant—shorter than that of the control means. In other words, the process can change faster than the measuring-and-control system can apply correction. This condition is the opposite of that existing in a temperature-control application.

It is an accepted fact that rate action, or direct-derivative action, will improve temperature control, where relatively long process-lags exist. Tests have shown that inverse-derivative action will benefit processes which have exceptionally short time-lags. This fact indicates that there must be some intermediate point where neither direct nor inverse derivative would be effectively applied. The dotted line in the graph serves to show an approximation of the transition from "direct" to "inverse" derivative. A range in which a narrow proportional band alone results in good control is also indicated.

In many instances, direct-derivative control has been used correctly; in other cases it has been misapplied through a lack of understanding of its function. As a result, the performance has varied widely, with reports stating: (1) control improved; (2) no improvement; (3) control made worse. All three of these reports were correct, but the processes had widely different time-constants. In the first case, the application was temperature—with a relatively long process lag. In the second case, which involved liquid level, there was less process lag and a narrow throttling range (without derivative or reset) would have given better control. The third application — liquid-flow control with an extremely short time-lag—could have been materially benefited by the use of inverse derivative.

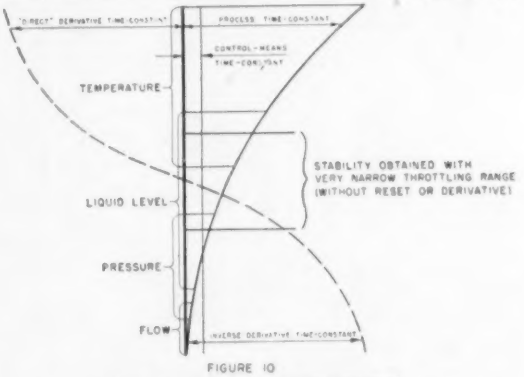


FIGURE 10
HYPOTHETICAL CURVES SHOWING APPLICATION OF "DIRECT" AND "INVERSE" DERIVATIVE ON PROCESS CONTROL

It appears, therefore, that the relationship of the process time-constant to the control-means time-constant should be seriously considered in determining whether "derivative" action is needed —and which type to use.

Standardization *of the* pH Scale

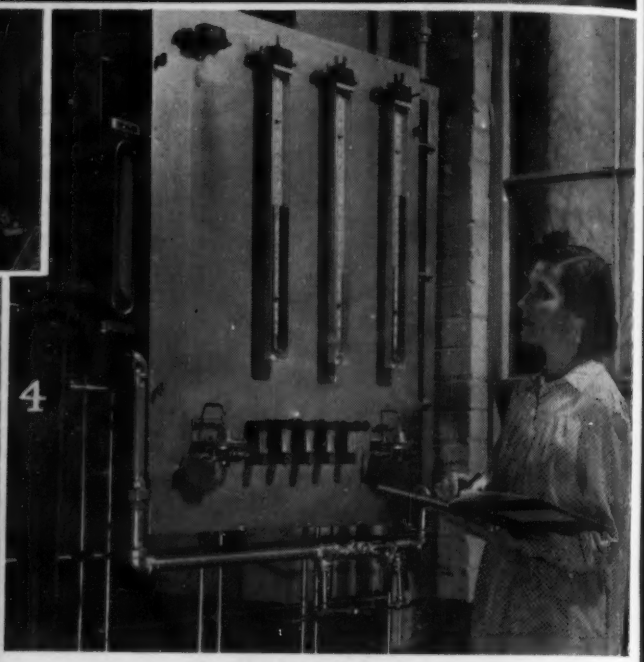
WASHINGTON, D. C.—The pH unit, used to express numerically the degree of acidity or alkalinity of aqueous solutions, may be defined in a number of ways, each resulting in a slightly different value for the pH of a given solution. Consequently, several pH scales, based upon various definitions, have met with equal favor among chemists. In view of the increasing need in science and industry for accurate determinations of acidity, the National Bureau of Standards is recommending the universal adoption of a single standard pH scale, analogous to the International Temperature Scale.

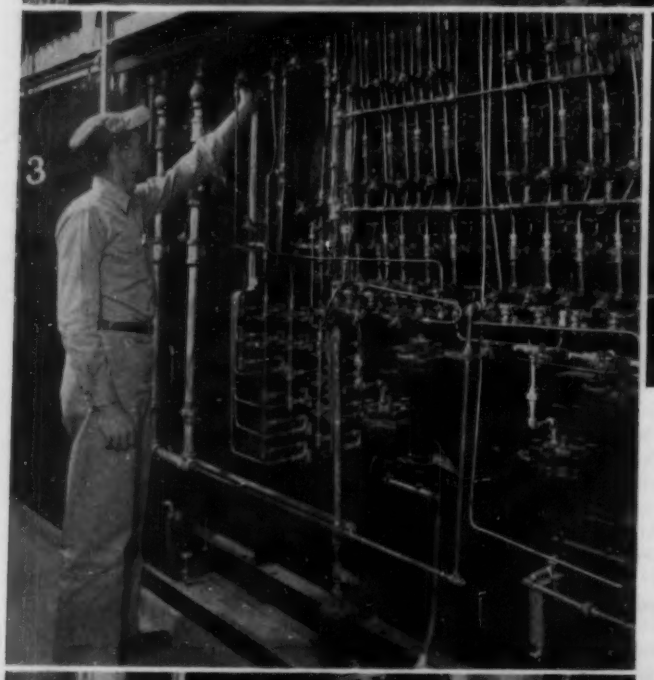
The convenient pH meters available commercially enable precise determinations of pH values in varied media to be made with ease and rapidity, but these values are based on a scale fixed by the pH assigned to the standards with which the instrument has been calibrated. The differences among scales result from different procedures, definitions, and assumptions employed in arriving at the pH of the standard.

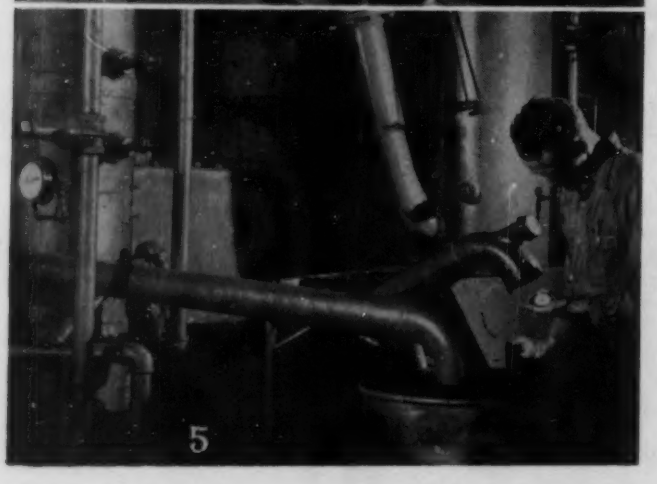
In an effort to encourage standard procedure in pH measurements, the NBS is now supplying four buffer materials in the form of Standard Samples of certified purity. These substances are acid potassium phthalate, potassium dihydrogen phosphate and disodium hydrogen phosphate (intended to be used together), and borax. The certificates furnished with these compounds specify the pH of certain aqueous solutions of the sample, which can provide fixed points on a pH scale.

In order to assign exact values to these fixed points, it was necessary to set up a scale based on a suitable definition of pH. Consideration of the advantages and limitations of several scales led to a choice of a modified activity scale as most convenient and practical for general use. Although the activity of a single ionic species can be simply defined only in very dilute solutions, the influence of the hydrogen-ion activity in chemical equilibria is of far-reaching importance.

The pH of the NBS standards is derived from measurement of the emf. of cells without liquid junction, in which they are used as electrolytes. These cells are specially designed, utilizing the highly-reproducible hydrogen and silver-silver chloride electrodes.







[FRONT-COVER PICTURE STORY]

Pilot Plant for Research on Coal Industry's Future

Pittsburgh Consolidation Coal Co.'s coal gasification pilot plant at Library (near Pittsburgh), Penna., designed and built in cooperation with Standard Oil Development Co. (Chemical Plants Div. of Blaw-Knox Co. was contractor.)

Purpose of this pilot plant is to study operability of fluidized coal gasification to reach conclusions regarding costs and commercial designs. In the process, fluidized coal or char is the feed material, which is reacted with steam and oxygen at a high temperature. The product is a mixture of carbon monoxide and hydrogen, known as water gas or "synthesis gas."

(1) Process building. Note that elaborate automatic-control instruments are centralized in a separate building.

(2) Analyzing products of coal carbonization with automatic semi-micro equipment.

(3) The extent of the instrumentation is brought out only partly by the front-cover photograph. This view shows some of the instrumentation piping. One of the staff is shown adjusting inert gas flow.

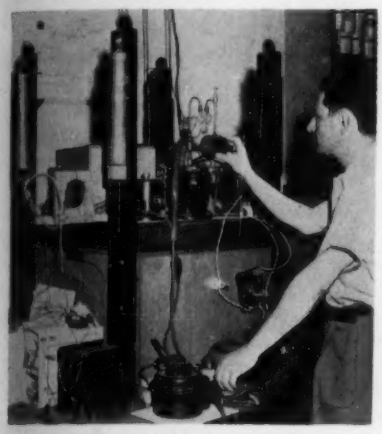
(4) Measuring gas flow for fluidized carbonization.

(5) Making a rapid determination of tar production rate from large coal carbonization pilot plant. This and other careful measurements of product yields are necessary to determine the economics of the new process.

Calibrating Hygrometers Below *the* Freezing-point

By **ARNOLD WEXLER, Mechanical Instruments Section, National Bureau of Standards, Washington 25, D. C.**

A HUMIDITY test apparatus developed and built in the Mechanical Instruments Laboratory of the National Bureau of Standards permits calibration and testing of hygrometers at temperatures below freezing. The increasing use of radiosondes for meteorological sounding of the atmosphere has created a marked need for information on the performance of the humidity-sensing element in the radiosonde under conditions of flight. The humidity test apparatus was developed under the sponsorship of the Bureau of Ships, Department of the Navy, to provide an instrument for the investigation of radiosonde hygrometer elements at the temperatures and air velocities encountered during a flight.



The humidity test apparatus, developed at the National Bureau of Standards for research, calibration, and testing hygrometers.

The function of the new Divided-flow Low-temperature Humidity Test Apparatus is to produce air of known relative humidity at temperatures from 0°C. to minus 40°C. In it, a current of dry air is divided into two streams, one of which is maintained dry while the other is saturated with respect to ice; finally the two are recombined. A proportioning valve is used to divide the flow of moisture-free air in a known ratio. One part is passed through a saturator over a series of trays containing ice, until it is completely saturated. It is then mixed in a mixing chamber, with the other part that has been maintained dry, and allowed to exhaust through a test chamber into the atmosphere. The saturator, mixing chamber, and test chamber are kept immersed in a constant-temperature bath. The hygrometer or other device, which is being subjected to air of known and constant humidity, is inserted into the test chamber.

The relative humidity in the test chamber is a function of (a) the fraction of air that passes through the saturator, (b) the total pressure in the saturator, (c) the total pressure in the test chamber, (d) the saturation pressure, and (e) the partial pressure of the water vapor in the test chamber. Under ideal conditions, which the apparatus closely approaches, all variables except one are eliminated, and the relative humidity becomes equal to the fraction of air that passes through the saturator.

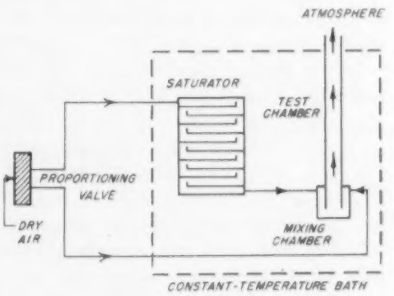
The essential functional units of the apparatus are the drying system, the proportioning system, the humidifying system, the mixing chamber, the test chamber, the cooling system, and the thermo-regulating system for temperature control. The drying system serves to remove all water from the air entering the apparatus by freezing in a dry ice-varsol bath. The dry air then passes through the proportioning system, the major feature of which is the proportioning valve. This valve consists of six orifices of equal cross-sectional area so arranged that by a turn of the knob of the valve the incoming air can be divided to produce any of seven ratios, 0, 1/6, 1/5, 1/2, 2/3, 5/6, and 1. The ratio is the fraction of air entering the valve that emerges through one exit channel.

The two air streams, upon leaving the proportioning system, flow through the humidifying system in parallel channels, thermally in contact with each other to bring about temperature equilibrium. Saturation of one stream is accomplished by allowing it to pass over a series of staggered ice-filled trays while the other stream passes over an identical path of dry shelves. The dry and saturated air are centrifugally mixed in a mixing chamber and discharged into the atmosphere through a 1 1/8" i.d. tube that serves as a test chamber. The saturators, mixing chamber and test chamber are immersed in a bath whose temperature is closely regulated.

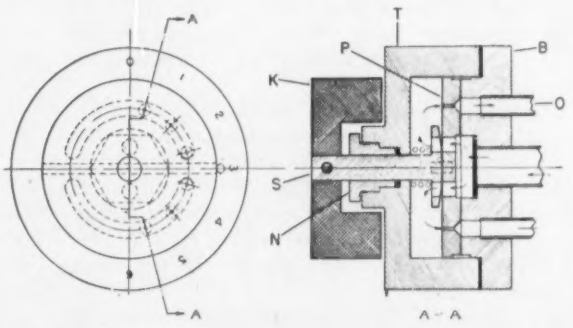
The over-all performance of the humidity test apparatus has been established by a series of gravimetric moisture determinations. For the temperature range of 0° to −40°C and for air velocities up to 1500 ft./min., this instrument produces air whose relative humidity is known within 3%.

While particularly suited for the investigation and calibration of hygrometers, psychrometers, and development instruments at temperatures below 0°C., the humidity test equipment may find further application in general research and testing where air of a known low dew-point or moisture content is desired. With such apparatus, devices placed in the test chamber can be subjected to discrete and almost instantaneous changes in relative humidity. Lag studies may therefore be easily made. The velocity of the air passing through the test chamber can be adjusted to any value up to 1500 ft/min.

Although this apparatus was designed primarily to fill a basic need in meteorology, the refrigeration and air-conditioning industries [and the instrument industry] may also find it useful. With this apparatus, it is now possible to calibrate readily and accurately the various humidity measuring instruments employed at low temperatures.



Simplified schematic diagram of NBS humidity test apparatus. By means of the proportioning valve a flow of moisture-free air is divided into two parts in a known ratio. One part is passed through the saturator, over a series of trays containing ice, until it is completely saturated. It is then mixed in the mixing chamber with the other part that has been maintained dry, and allowed to exhaust through the test chamber into the atmosphere. The saturator, mixing chamber, and test chamber are kept immersed in a constant-temperature bath. The hygrometer or other device, which is being subjected to air of known and constant humidity, is inserted into the test chamber.



Cross-sectional view of the proportioning valve showing the flow of air.

"HEAT INERTIA" *in* Problems *of* AUTOMATIC CONTROL *of* TEMPERATURE

By VICTOR BROIDA, Consulting Engineer, Paris, France

PART II

We shall now consider some problems related to *continuous* automatic control systems. We shall discuss three of the simpler types of automatic controllers.

We have, on one hand, automatic temperature control as a direct function of time elapsed alone—which is the floating control—and, on the other hand, control as a direct function of temperature alone (itself a function of the time elapsed) which is the positioning control with throttling action alone; finally, it is easy to imagine a combination of both, insuring automatic control of heat input to the heating unit simultaneously as a direct function of time elapsed and of temperature: this is the positioning control with both throttling action and automatic reset.

In the first of these systems, the automatic temperature controller commands the heat input to the heating unit in a way absolutely independent of the temperature variations inside the latter, once the action of this controller starts. In this way, for instance, when the temperature inside the heating unit drops below the chosen lower limit of control and consequently starts the action of the automatic temperature controller, the latter increases constantly and continuously the heat input to the heating unit until the moment when the original temperature is again restored or overshot and when, therefore, its action stops or is exerted in an opposite direction. This increase of the heat input is gradual, in this case, and continues as a function of the time elapsed whatever may be the temperature variations inside the heating unit, as long as the original temperature having existed inside the latter is not again restored or overshot.

The case is quite different with the second system of control which operates entirely as a function of temperature variations inside the heating unit and independently of time elapsed; in this case there is, in reality, no starting of the automatic temperature controller action at a given moment but a constant action of this controller as long as the balance is not restored, this action insuring a definite variation of the heat input to the heating unit for each variation of the temperature inside the latter and, therefore, a compensation of each temperature variation by a corresponding variation of the heat input.

It is obvious, on the other hand, that in this case to each temperature existing inside the heating unit corresponds a definite value of the heat input to the latter, so that when a variation of the flow of heated fluid drawn off from the heating unit takes place and requires, before balance can be restored, a corresponding change in the heat input, this balance is, of course, restored for a temperature different from that prior to this disturbance; this method of control is not therefore isothermic.

Finally, in the case of the third combined method of control which involves, besides the positioning control of the heat input to the heating unit as an exclusive function of the temperature existing inside the latter, a floating control as a function of the time elapsed, the absolute link existing under the preceding method of control between the values of the temperature inside the heating unit and the corresponding values of the heat input to the latter exists no more so that this new method of control is simultaneously positioning and floating. On the other hand, the control is isothermic as the action of the automatic temperature controller cannot stop—just as it does not stop in the case of ordinary floating control—until the original temperature is again reached or overrun. This combined method of control comprises, as we could expect, the features of both preceding methods of control which are, in fact, only particular instances of the latter.

In order to avoid unnecessary calculations, we shall therefore study the application of general equation (1) to the most general case of continuous automatic control which is that of positioning control with throttling action and automatic reset; we shall then study the adaptation of the general formulae which we shall thus obtain and of the conclusions to which they shall lead to the two particular instances of floating control and of positioning control with throttling action alone.

In the general case under review, a given variation of the heat input to the heating unit per unit of time depends, therefore, in absolute value, on one hand on a given variation of the time elapsed and, on the other hand, on a given variation of the temperature existing inside the heating unit; we can, therefore, write—if we call K_1 and K_2 two coefficients:

$$(dQ) = (K_1 dt) + (K_2 d\theta)$$

In order to determine the signs of the different parts of this relation, we must remember that when the temperature increases—that is when $d\theta$ is positive—the automatic temperature controller decreases the heat input to the heating unit, i.e., gives dQ a negative value and vice versa; this means that dQ and $d\theta$ have always opposite signs.

As the time elapsed increases always, whatever may be the direction in which the temperature inside the heating unit is altered, dt is always positive; we can conclude that the sign in front of the term $K_1 dt$ is negative when the temperature inside the heating unit increases and positive when this temperature decreases, and that this sign changes, therefore, from one case to another.

On the other hand, as the term $K_2 d\theta$ has always a sign opposite to that of $d\theta$, we can conclude that the sign in front of this term is always negative; under these conditions, we can write:

$$dQ = \mp K_1 dt - K_2 d\theta$$

the sign in front of the term $K_1 dt$ being $(-)$ when the temperature increases and $(+)$ when this temperature decreases.

We shall study, as an example, the case of a sudden increase of the flow of heated fluid drawn off from the heating unit, which corresponds to a decrease of the temperature.

If we integrate the above equation, between the limits Q_1 and Q, we obtain:

$$Q = Q_1 + K_1 t + K_2 (\theta_1 - \theta) \qquad \ldots(20)$$

If we compare formula (20) with the general relation

$$Q = Q_1 + f(\theta, t),$$

we find: $f(\theta,t) = K_1 t + K_2(\theta_1 - \theta)$

Replacing $f(\theta,t)$ by its above value in general equation (1) we find that the latter becomes, in the case of continuous automatic control:

$$-m\frac{d\theta}{dt} = \left[\frac{\theta - \theta_0}{\theta_1 - \theta_0}(v+1) - 1\right] Q_1 - K_1 t - K_2(\theta_1 - \theta)$$

from whence

$$-m\frac{d\theta}{dt} = \left[\frac{(v+1)Q_1 + K_2(\theta_1 - \theta_0)}{\theta_1 - \theta_0}\right](\theta - \theta_1) + vQ_1 - K_1 t \qquad \ldots(21)$$

This differential equation corresponds to a decrease of temperature inside the heating unit below the original temperature θ_1. This decrease of temperature will have the form of the decreasing branch of the curve $\theta(t)$ in Fig. 5 and will continue down to the temperature θ_2 at which the balance between the heat input to the heating unit and the heat output carried away with the heated fluid will be restored.

The slope of the curve $\theta(t)$ at the moment of the disturbance is determined by applying the condition that $\theta = \theta_1$ whence $t = 0$ to equation (21). We then find: $d\theta/dt = -(vQ_1/m)$, a relation with which we are already familiar, having obtained it in the case of

heating units not provided with any automatic temperature controller.

We shall now determine the temperature of balance θ_3. We must have, for this temperature, $d\theta/dt=0$, as it corresponds to a state of balance.

If we call t_1 the time required by the temperature inside the heating unit to pass from θ_1 to θ_3, equation (21) becomes:

$$\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{\theta_1-\theta_0}\right](\theta_3-\theta_1)+vQ_1-K_1t_1=0$$

from whence

$$\theta_3=\theta_1-\left[\frac{(\theta_1-\theta_0)(vQ_1-K_1t_1)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right] \qquad \ldots(22)$$

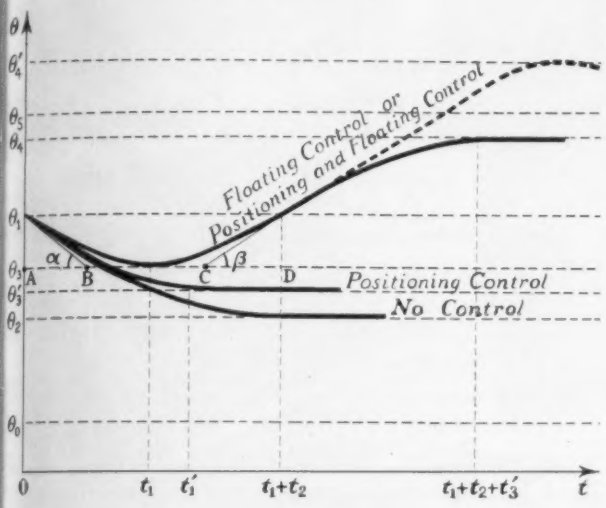


Fig. 5

This formula gives the value of θ_3 as a function of t_1 which we do not know for the moment. We shall determine later the value of t_1 and shall then give to formula (22) an explicit form.

We shall now determine the equation of the decreasing branch of the curve $\theta(t)$ in Fig. 5.

By inspection it is seen that equation (21) may be written in the form:

$$d\theta/dt+a\theta=bt+d,$$

whose solution is:

$$\theta=\frac{b}{a^2}(at-1)+\frac{d}{a}+c\exp\left[-at\right] \qquad \ldots(22a)$$

By introducing the condition that $\theta=\theta_1$ when $t=0$, we obtain:

$$c=\frac{b}{a^2}-\frac{d}{a}+\theta_1.$$

Substituting the appropriate values of a, b, c and d in the above equation we have:

$$\theta=\theta_1-\left[\frac{\theta_1-\theta_0}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\left[vQ_1+\frac{mK_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\times$$

$$\left\{1-\exp\left[-\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{m(\theta_1-\theta_0)}t\right]\right\}+\frac{K_1(\theta_1-\theta_0)t}{(v+1)Q_1+K_2(\theta_1-\theta_0)} \qquad (23)$$

which is the equation of the decreasing branch of the curve $\theta(t)$ in Fig. 5.

We can now determine the time, t_1, required for the temperature to change from θ_1 to θ_3. By differentiating equation (22a) we obtain:

$$\frac{d\theta}{dt}=\frac{b}{a}-ca\exp\left[-at\right] \qquad \ldots(24)$$

When $t=t_1$, $\theta=\theta_3$ and $d\theta/dt=0$. Equating equation (24) to zero we obtain:

$$t_1=\frac{1}{a}\log\frac{ca^2}{b},$$

which, upon substitution of the values for a, b, and c, results in:

$$t_1=\left[\frac{m(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\log\left\{1+\frac{vQ_1[(v+1)Q_1+K_2(\theta_1-\theta_0)]}{mK_1(\theta_1+\theta_0)}\right\}, \qquad \ldots(25)$$

an expression of t_1 which will allow us to give, in turn, an explicit form to formula (22) which gives the value of θ_3 as a function of t_1.

If we replace in formula (22) t_1 by its value which we have just determined, we have:

$$\theta_3=\theta_1-\frac{vQ_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}+\left\{\frac{mK_1(\theta_1-\theta_0)^2}{[(v+1)Q_1+K_2(\theta_1-\theta_0)]^2}\right\}\times$$

$$\log\left\{1+\frac{vQ_1[(v+1)Q_1+K_2(\theta_1-\theta_0)]}{mK_1(\theta_1-\theta_0)}\right\} \qquad \ldots(26)$$

We have thus determined all the elements of the decreasing branch of the curve $\theta(t)$ in Fig. 5, of which formula (23) gives us the equation, formula (25), the time required for balance t_1 and formula (26), the temperature of balance θ_3.

We shall now prove that there is really a balance between the heat input to the heating unit and the heat output carried away by the heated fluid at the temperature of stabilization θ_3; we shall then see what happens to curve $\theta(t)$ in Fig. 5 for a time $t>t_1$ in the different cases which can be considered.

If we take formula (22) which gives in its original form, the value of θ_3, we can deduce from it the value of the term K_1t_1 as a function of θ_3, that is:

$$K_1t_1=vQ_1-\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{\theta_1-\theta_0}\right](\theta_1-\theta_3)$$

On the other hand, if we call Q_3 the heat input per unit of time to the heating unit at the temperature θ_3, i.e., when $t=t_1$, the formula (20) gives us:

$$Q_3=Q_1+K_1t_1+K_2(\theta_1-\theta_3) \qquad \ldots(27)$$

We have seen at the beginning of this essay, when we were determining formula (1) that the new value of the flow of heated fluid was equal to: $q_3=(v+1)q_1=\dfrac{(v+1)Q_1}{\theta_1-\theta_0}$

If we replace $\dfrac{(v+1)Q_1}{\theta_1-\theta_0}$ by q_3 in the preceding relation, we obtain:

$$Q_3=q_3(\theta_3-\theta_0)$$

and there will be a balance between the heat input Q_3 and the heat output $q_3(\theta_3-\theta_0)$ carried away by the heated fluid at the temperature θ_3.

We have therefore proved that there will be a balance for $t=t_1$, i.e., at the temperature θ_3. Let us see now what will happen as time elapses again after the temperature of balance θ_3 has been reached.

Two quite different cases are to be considered: the case of floating automatic control or of throttling automatic control with automatic reset, on one hand, and that of positioning automatic control, on the other hand.

In the first case, in spite of the fact that a state of balance is secured at the temperature θ_3 the controller action will not stop, as we have already seen, until the original temperature θ_1 is again restored or over-run; the controller will therefore continue to actuate the heat input to the heating unit and shall give to this input increasing values higher than Q_3, so that the temperature will increase above θ_3 and shall follow the increasing branch of the curve $\theta(t)$ in Fig. 5 as long as the original temperature θ_1 is not restored or over-run.

On the other hand, in the case of positioning automatic control, the variations of the heat input to the heating unit being dependent only on the variations of the temperature inside the heating unit and the latter being stabilized, it will be as well for this heat input which will remain equal to Q_3; the temperature inside the heating unit will therefore remain—unless new disturbances occur in the meantime—constantly equal to θ_3 and will follow the horizontal dotted line tracing in Fig. 5.

In this last case, the constant K_1 peculiar to the variations of the heat input to the heating unit as a function of the variations of the

time elapsed will be obviously equal to 0 and it will be sufficient to make $K_1=0$ in equation (23) in order to obtain the corresponding equation in the case of positioning automatic control.

On the other hand, if we proceed in this way with formula (25) we shall find $t_1'=\infty$ which means that, in this case, the curve $\theta(t)$ will tend to an asymptotic limit $\theta=\theta_3'$. The exact formulae (25) and (26) cannot be therefore, used in the case of positioning automatic control and we shall replace them, in this case by corresponding approximate formulae, by determining the time required for the temperature inside the heating unit to pass from θ_1 to $\theta_3''=\theta_3'+1°$.

If we make $K_1=0$ in formula (22), we obtain:

$$\theta_3'=\theta_1-\frac{vQ_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)} \qquad \ldots(26a)$$

On the other hand, if we introduce in equation (23) the values of:

$$\theta=\theta_3''=\theta_3'+1°=\theta_1-\frac{vQ_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}+1$$

and $t=t_1'$ we shall obtain the approximate value of t_1' (with an approximation of 1°); we obtain thus, first of all, the equation of the curve $\theta(t)$ in the case of positioning automatic control:

$$\theta=\theta_1-\left[\frac{vQ_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\times \left\{1-\exp\left[-\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{m(\theta_1-\theta_0)}t\right]\right\} \qquad \ldots(23a)$$

and, substituting θ_3'' for θ:

$$t_1'=\left[\frac{m(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\log\left[\frac{vQ_1(\theta_1-\theta_0)}{(v+1)Q_1+K_1(\theta_1-\theta_0)}\right] \qquad \ldots(25a)$$

We have seen what happens in the particular case of positioning automatic control; we shall continue now to study the increasing branch of the curve $\theta(t)$ in Fig. 5 which exists, as we have seen in the case of floating automatic control and in the most general case of throttling automatic control with automatic reset.

We shall use in this investigation the formulae which we have determined for the decreasing branch of the same curve after having altered them in a convenient way; this will be correct as all these formulae are based on general equation (1) and as the latter applies as we have already seen, to the case of decrease of the temperature inside the heating unit as well as to that of its increase.

If we examine formula (20) we see that when temperature inside the heating unit decreased from θ_1 to θ_3 the heat input to the latter per unit of time was expressed, for a given temperature θ, by the relation:

$$Q=Q_1+K_1t+K_2(\theta_1-\theta)$$

This relation is based on the elementary relation which we have obtained previously and which can be written as follows:

$$dQ=K_1dt-K_2d\theta$$

We have put up to now, in front of the term K_1dt the sign (+) as we considered a decrease of temperature and we shall continue to do so when studying the increasing branch of the curve $\theta(t)$ in Fig. 5 despite the fact that the case considered now is that of an increase of temperature. The reason of this choice of sign is that, the controller action being started by a decrease of the temperature below the limit θ_1, this action will continue in the same direction, whether the case considered is that of a decrease of temperature from θ_1 to θ_3 or of an increase of this temperature from θ_3 to θ_1 as long as the original temperature θ_1 is not again restored and overshot; the controller will therefore continue to increase continuously the heat input to the heating unit—i.e., to give dQ positive values—for the increasing branch of the curve $\theta(t)$ just as it did for its decreasing branch and a reverse action of this controller will not be possible until the original temperature θ_1 is again reached and over-run.

It will be therefore sufficient to replace θ, by θ_3 and Q_1 by Q_2 in equation (20). We obtain thus:

$$Q=Q_2+K_1t+K_2(\theta_3-\theta)$$

If we replace Q_2 by its value given by formula (27) we will have:

$$Q=Q_1+K_1(t+t_1)+K_2(\theta_1-\theta) \qquad \ldots(28)$$

a relation which applies to the increasing branch of the curve $\theta(t)$

If we compare formula (28) with formula (20) which gives the same relation for the decreasing branch of the curve $\theta(t)$, we see that it is sufficient to replace in the latter t by $t+t_1$ in order to obtain formula (28); we shall be able therefore to obtain all the formulae of the increasing branch of the curve $\theta(t)$ by replacing in the corresponding formulae of its decreasing branch t by $t+t_1$.

In this way, if we replace t by $t+t_1$ in formula (21) we have:

$$-m\frac{d\theta}{dt}=\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{\theta_1-\theta_0}\right](\theta-\theta_1)+vQ_1-K_1(t+t_1) \qquad \ldots(29)$$

If we make the same substitution in formulae (23) and (24) we have respectively:

$$\theta=\theta_1-\left[\frac{\theta_1-\theta_0}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\left[vQ_1+\frac{mK_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\times \left\{1-\exp\left\{-\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{m(\theta_1-\theta_0)}\right](t+t_1)\right\}\right\} +\left[\frac{K_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right](t+t_1) \qquad \ldots(30)$$

which is the equation of the increasing branch of the curve $\theta(t)$ in Fig. 5 and:

$$-m\frac{d\theta}{dt}=\left[vQ_1+\frac{mK_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\times \exp\left\{-\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{m(\theta_1-\theta_0)}\right](t+t_1)\right\}-\frac{mK_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)} \qquad \ldots(31)$$

We shall determine now the time t_2 required by the temperature inside the heating unit to pass from θ_3 to θ_1. In order to do this, we shall, first of all, make in formulae (29) and (31) $\theta=\theta_1$ and $t=t_2$ which will give us respectively:

$$-m\left(\frac{d\theta}{dt}\right)_{t=t_2}=vQ_1-K_1(t_2+t_1)$$

and:

$$-m\left(\frac{d\theta}{dt}\right)_{t=t_2}=\left[vQ_1+\frac{mK_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\times \exp\left\{-\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{m(\theta_1-\theta_0)}\right](t_2+t_1)\right\}-\frac{mK_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}$$

These expressions of $-m\left(\frac{d\theta}{dt}\right)_{t=t_2}$ being identical, we can write:

$$K_1(t_1+t_2)=\left[vQ_1+\frac{mK_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right] \left\{1-\exp\left\{-\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{m(\theta_1-\theta_0)}\right](t_1+t_2)\right\}\right\}$$

If we introduce the value of the exponential terms from formula (25), we can write:

$$t_1+t_2=\frac{vQ_1}{K_1}+\left[\frac{m(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\times \left\{1-\exp\left\{-\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{m(\theta_1-\theta_0)}\right]t_2\right\}\right\} \qquad \ldots(32)$$

We can deduce from this formula, by replacing t_1 again by its value given by formula (25):

$$t_2=\frac{vQ_1}{K_1}+\left[\frac{m(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\times \left\{1-\exp\left\{-\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{m(\theta_1-\theta_0)}\right]t_2\right\} -\log\left\{1+\frac{vQ_1[(v+1)Q_1+K_2(\theta_1-\theta_0)]}{mK_1(\theta_1-\theta_0)}\right\}\right\} \qquad \ldots(33)$$

Continued on Page 254

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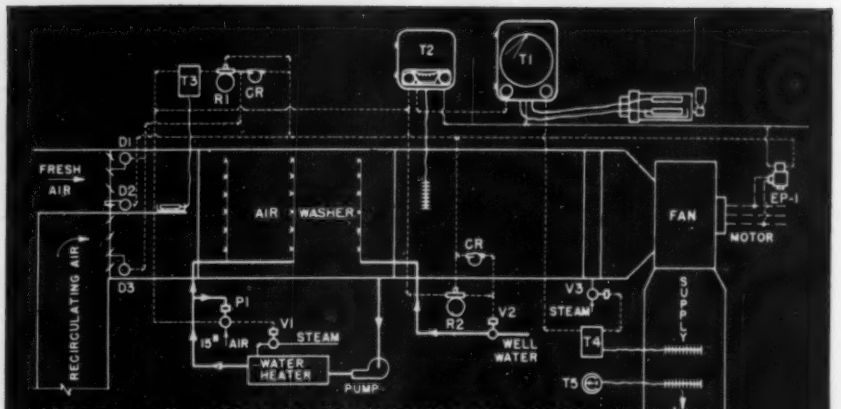

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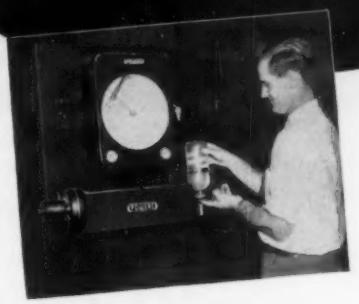

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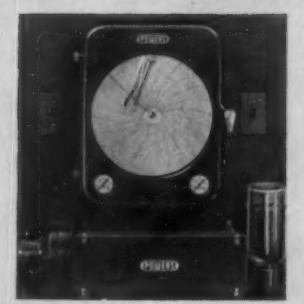

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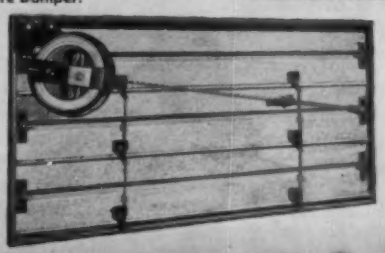

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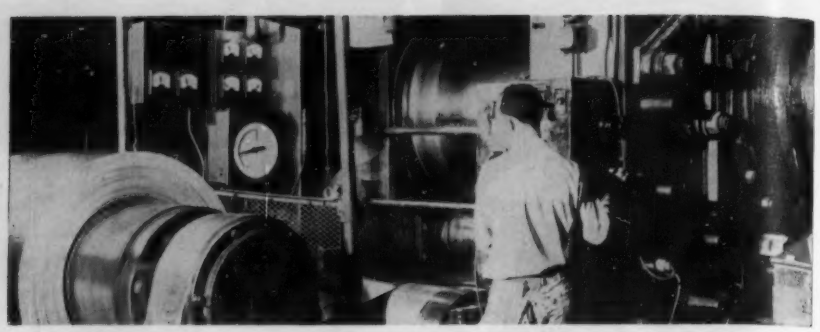
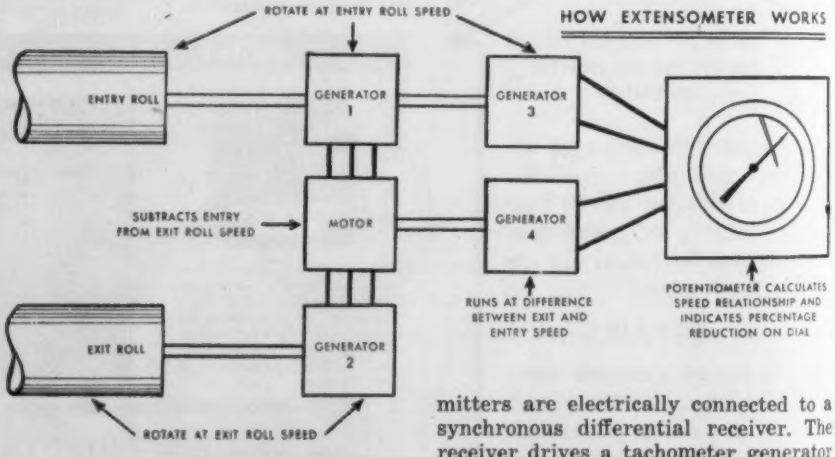


Operator watching pointer on circular dial of extensometer manipulates temper mill controls in a U. S. Steel Corporation subsidiary plant.

Extensometer Continuously Records Percent *of* Extension *on* New Strip Temper Pass Mill

PITTSBURGH, Penna.—According to a report by G. H. Rendel, Research Laboratory, Carnegie-Illinois Steel Corp., plant tests of a unique type of continuously-indicating and recording extensometer for measuring the percentage of extension of strip steel during rolling in temper pass mills have demonstrated the utility and accuracy of the instrument. It was common practice before installation of the extensometer to measure strip extension by a hand-operated gage; and such measurements could not be obtained satisfactorily at mill operating speeds in excess of approximately 200 feet per minute. Since installation of the extensometer, mill operators have abandoned the practice of measuring extension by manual methods and are relying entirely upon the instrument for all extension measurements, at operating speeds up to 2000 feet per minute.

The extensometer is designed to indicate and record the percentage of extension being effected on the temper pass mill, by measuring the entry and delivery speeds of the strip, and comparing the differential between the two speeds with the entering strip speed. The entry-delivery strip speed differential is obtained (see diagram) by a system consisting of two synchronous transmitters, one driven by the entry and the other driven from the delivery deflector roll. The synchronous transmitters are electrically connected to a synchronous differential receiver. The receiver drives a tachometer generator that generates a voltage proportional to the true differential speed. A second tachometer generator is driven by the entry deflector roll and generates a voltage proportional to the strip entry speed. These two voltages are applied to a self-balancing potentiometer which indicates the ratio of the two voltages. Since this ratio is proportional to the strip extension, the potentiometer is calibrated accordingly.



The equipment is designed to operate with an accuracy of approximately 0.04 percent over a range of approximately

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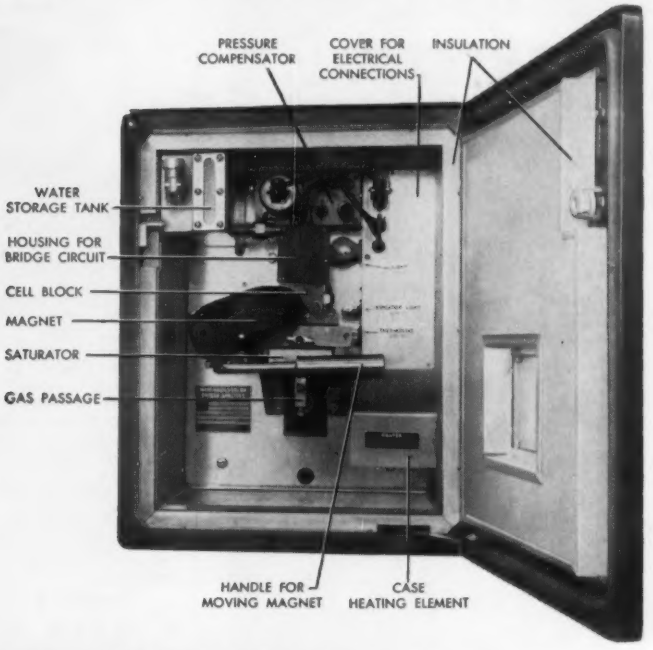

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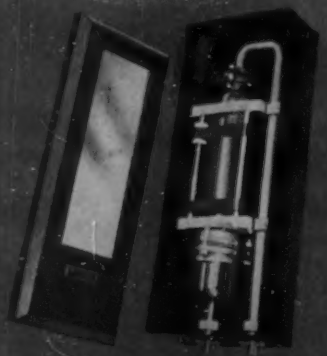

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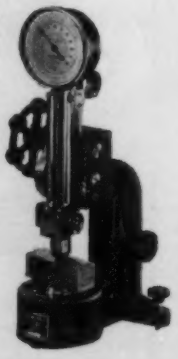

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8 to 100 percent of normal strip operating speed, while measuring extension varying from 0.1 percent to 8 percent.

A number of tests were conducted to check the performance and accuracy of the instrument on an actual installation, including numerous tests in which the indicated extension was compared with that of measurements obtained from marked test coils. The test coils were scribed prior to temper rolling and the extension was determined by computing the increase in measured distance between the scribe marks after temper rolling. The results disclosed that approximately 60 percent of the tests indicated the same amount of extension by both methods and that the maximum deviation between the extensometer indication and the measured extension was 0.1 percent.

New International Temperature Scale

WASHINGTON, D.C.—According to Technical Report 1327 of the National Bureau of Standards, the Bureau began using, on January 1, 1949, the definitions of the International Temperature Scale of 1948 both in its own research program and in calibrating instruments for other scientific and industrial purposes. Based on a draft prepared by members of the Bureau staff, the new scale was adopted at Paris by the Ninth General Conference on Weights and Measures in October 1948, and the official text was approved for publication before the end of the year. This is the first revision of the International Temperature Scale since its adoption at Paris in 1927 by the Seventh General Conference. The experimental procedures* by which the scale is to be realized are substantially unchanged; but certain refinements, based upon experience, have been incorporated to make the scale more uniform and reproducible.

The experimental difficulties inherent in the measurement of temperature on the thermodynamic scale (an ideal scale based on energy changes in a Carnot cycle) led to the establishment in 1927 of the practical scale known as the International Temperature Scale. This scale is based upon six reproducible equilibrium temperatures, or "fixed points," to which numerical values are assigned, and upon specified interpolation formulas relating temperature to the indications of specified standard temparture-measuring instruments. The scale is designed to conform, as nearly as practicable, to the thermodynamic Celsius** scale as it is now known. At the present time, however, it is possible to obtain values of temperature on the International Temperature Scale more

*See: "Unshakable Foundations of Temperature Measurement," by M. F. Behar, *Instruments*, September 1940, pages 230-236, 268-270.

**The Ninth General Conference decided to abandon the designation "Centigrade" and use "Celsius" instead.

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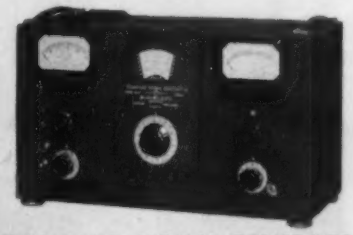

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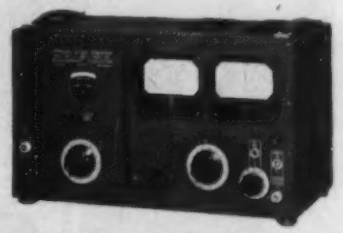
Frequency range: 75 kc. to 30 mc. Output 0.1 microvolt to 2.2 volts.
MODEL 65B



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5 to 100,000 cycles. Recommended for AM, FM and television testing.
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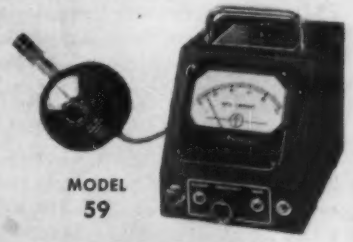

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Also, the capabilities of the Type 275-A are not limited to the study of only rotating devices. All the applications above-stated are feasible with this instrument. Thus if you desire to know the light distribution from an automobile headlight, or the stress limits of a drive shaft, or the maximum effectiveness of a pump—then you can profitably use the Du Mont Type 275-A.

An essential part of this indicator is its two-phase generator (supplied with instrument) which is coupled to the machine under study to provide the circular time base, in perfect synchronization with shaft rotation.

The price of the Type 275-A (Cat. No. 1250-E) is $390. Why not consult us now about its application to your particular problem.

★ Literature on request. Demonstrations arranged — no obligation, of course.

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accurately than on any thermodynamic scale.

The International Temperature Scale of 1927 proved useful in providing a stable, uniform, and precise basis for obtaining temperatures. However, since the adoption of this scale, the increasing precision attained in temperature measurements had made it apparent that some revision was desirable in order that measurements of physical constants (for example, the freezing and boiling points of pure compounds) might be made on a more exactly comparable basis by laboratories in all parts of the world. Because of the present leadership of the United States in the fields of heat and thermometry, the major responsibility for proposing and obtaining agreement on the changes fell to the National Bureau of Standards. After many consultations with scientists and laboratories in this country and abroad, the Bureau prepared a draft which formed the basis of the document finally adopted by the General Conference as the International Temperature Scale of 1948.

The six fixed points of the 1927 scale were the boiling point of oxygen (182.97 C.), the ice point (0.000 C.), the steam point (100.000 C.), the boiling point of sulphur (444.60 C.), the melting point of silver (960.5 C.), and the melting point of gold (1063 C.). From —190 C. to 660 C., the measure of temperature was based on the indications of a standard platinum resistance thermometer used in accordance with specified formulas. From 660 C. to the gold point, a platinum-vs.-platinum-rhodium thermocouple was the reference instrument; and above the gold point the optical pyrometer has been standard.

The same fixed points, with one slight modification are specified in the 1948 scale; and the laboratory procedures for obtaining temperatures between fixed points are essentially the same as those previously used. Only two revisions in the definition of the scale result in appreciable changes in the numerical values assigned to measured temperatures. One of these is the change in the value for the silver point from 960.5 C. to 960.8 C., which affects temperatures measured with the standard thermocouple. Thus, in the range between 630 C. and 1063 C., numerical values of temperature are higher than on the 1927 scale, the maximum difference being about 0.4 degree near 800 C. The adoption of a new value, 1.438 cm.-deg. (instead off 1.432 cm.-deg.), for the constant c_2 in the radiation formulas changes all temperatures above the gold point. In the new scale, Planck's radiation formula is specified instead of Wien's for calculating temperatures above the gold point as observed with an optical pyrometer. Since Planck's law is consistent with the thermodynamic scale even at high temperatures, this change removes the upper limit to the scale formerly imposed by the use of Wien's law.

There are several other important

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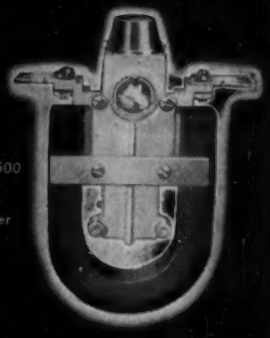

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New

250 VA STABILINE IE

VOLTAGE REGULATOR

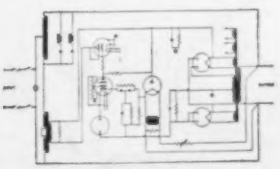
The new 250 VA STABILINE Type IE51002 is the latest addition to the Superior Electric line of dependable instantaneous electronic automatic voltage regulators. It's easy to carry this compact, portable unit to any location in shop or laboratory — from one test station or operation to another. And packed into its black, wrinkle-finished case are the same superior characteristics of workmanship and performance found in STABILINES of larger capacity.

Here are the ratings for the new 250 VA STABILINE Type IE51002 — **Input Voltage Range:** 95 to 135 volts. **Output Voltage Range:** adjustable between 110 and 120 volts. **Rated Output:** 0 to 250 volt-amperes. **Frequency in Cycles:** 60 ± 10%. **Load Power Factor:** 0.5 lagging to 0.9 leading. **Waveform Distortion:** *never* exceeds 3%. **Stabilization:** ± 0.1 volts of preset value. **Regulation:** ± 0.15 volts of preset value. **Recovery Time:** 3 to 6 cycles.

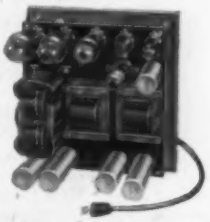
Among the many advantages of this new voltage regulator is the fact that all tubes but one are standard — and the non-standard tube is made by a well-known manufacturer. Tube replacement is thereby made easy — at no extra trouble to you. The 250 VA STABILINE Type IE51002 is easy to order, too. There are no annoying suffixes to watch on your order — no "extras" to buy. The standard cataloged model provides equal or improved characteristics over so-called "special designs".

Each unit is complete, offering all the superior features. Operation is simple. No extra parts or accessories are needed — no special adjustments to achieve maximum performance and service.

The new 250 VA STABILINE Type IE51002 is a self-contained unit measuring 11½" x 11½" x 10¼". It's complete with carrying handle, 6' cord and plug, 2 outlet receptacles and a pair of Superior 5-Way Binding Posts. Fuses are located in the input for complete protection. There's a handy "on-off" switch, pilot light and a screwdriver adjustment for output voltage.



Connection diagram showing operating circuit of the new 250 VA STABILINE Type IE51002.



Rear view shows compactness and fine workmanship in IE51002.

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STRAIGHT LINE TEMPERATURE CONTROL

For Use With Pyrometer Controllers

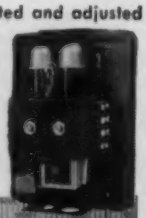
Anticipates Temperature Change Eliminates Overshoot and Undershoot

Now with XACTLINE Straight Line Temperature Control you can increase the efficiency of your Pyrometer Control Instruments (either Millivoltmeter or Potentiometer Type) to an amazing degree. Now you can hold tolerances as close as 1/5°F. plus or minus and power "on-off" cycles as low as 3 seconds.

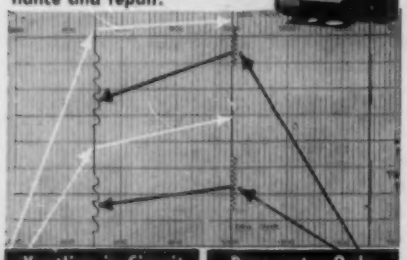
For XACTLINE, operating in the thermocouple circuit, ANTICIPATES the most minute heat variations on both heating and cooling cycles, thereby enabling your pyrometer controller to control far more closely than otherwise possible.

This *Anticipation Factor* means that XACTLINE causes the conventional pyrometer controller to respond to a millivoltage impulse up to 90% less than that normally required, (the controlling pyrometer functions *only* when the desired temperature range has *already been exceeded*).

XACTLINE is laboratory tested and adjusted . . . does not require readjustment or coordination with other controllers.



NO gears, cams, shafts, bearings or other rotating or sliding parts. Simple design eliminates usual maintenance and repair.



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modifications in the scale which cause little or no change in numerical values for temperatures but serve to make the temperatures more definite and reproducible. For example, the standard platinum resistance thermometer is to be used as a reference instrument from the oxygen point to the freezing point of antimony (about 630 C.), rather than over the range from —190 C. to 660 C. Platinum of higher purity is also specified for the standard resistance thermometer and standard thermocouple, and smaller permissible limits are given for the emf. of the standard thermocouple at the gold point.

Spectroscopy Speeds Routine Stainless-steel Analyses

PITTSBURGH, Penna.—Rapid differentiation of grades and detection of residual elements, in stainless steels at the Wood Works of Carnegie-Illinois Steel Corporation are now effected by spectroscopic methods. This U. S. Steel Corp. subsidiary plant has found the procedure valuable for making rapid and accurate qualitative determinations, especially in identifying stainless steel grades which owe their identity to one or more modifying elements. These elements include the columbium of Type 347, titanium of Type 321, molybdenum of Type 316, copper and molybdenum of Type 315, and others. Semi-quantitative estimates from visual or photographic examination are possible for some elements common to stainless steel when they are present in small percentages. This makes possible, for example, such separations as Type 410 twelve percent chromium steel from Type 405 twelve percent chromium steel containing aluminum.

The analyzer at Wood Works consists of a fixed-deviation glass-prism spectrometer mounted on a portable cabinet. The range of the spectrometer covers the visible spectrum: it may be increased slightly by the use of photographic attachments.

The arc stand is versatile with respect to the size of sample it will accommodate, and is contained in a housing with a safety switch on the door jamb to facilitate rapid changing of samples and to permit these changes to be made without danger to the operator. The arc functions on 220-volt

WHEN A FELLER NEEDS A FRIEND

By Phil Putnam

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In this department we report each month new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

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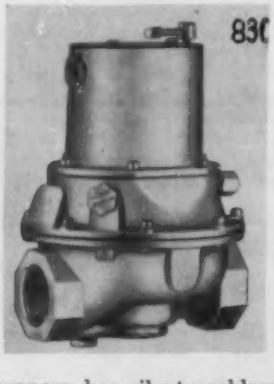
Motorized-valve Temperature Controller

New combination motorized-valve temperature controller is for on-off, two-position, floating or proportional control. Remote-bulb thermal system positions powerful motorized valve in response to temperature changes. Unit is available with temperature ranges between minus 50 and plus 700 deg. F. and with different sizes and types of valves. Assembly includes valves, linkage, motor, transformer and temperature controller.—*Brown Instrument Co., Wayne and Roberts Aves., Philadelphia 44, Pa.*

Mention No. 301 when filling out card

Electric-diaphragm Gas Valve

New electric-diaphragm gas valve for controlling all types of gas to space and unit heaters as well as central, floor and



wall furnaces, has silent packless valve and no bellows to impede operation. Consumes 5 watts current, operates on low or line voltages and is available in standard or manual models with or without electric trip. Body is die-formed aluminum. Available in seven sizes from 0.5 to 1.5 in. IPS, and from 2.75 to 5.25 in. diameter.—*General Controls Co., 801 Alien Ave., Glendale 1, Calif.*

Mention No. 302 when filling out card

D-c., A-c. Chopper

New "Type 240" d-c., a-c. chopper converts d.c. to pulsating d.c. or a.c. in range of 10 to 500 cps. Used with servomechanisms, thermocouples and low-level applications for operation at 0.05 amps. or less. Unit is electromechanical device for demodulation, rectifying or square-wave generation uses. Height 2.5 in.; diam. 1.5 in.; 8-prong octal base. Replaces in this range maker's "Type 222" chopper which now has range of 0.05 to 0.5 amps. Both have s-p.d-t. contact arrangements. — *Stevens-Arnold, Inc., 22 Elkins St., South Boston 27, Mass.*

Mention No. 303 when filling out card

Combination Polyphase Watthour and Thermal Demand Meter

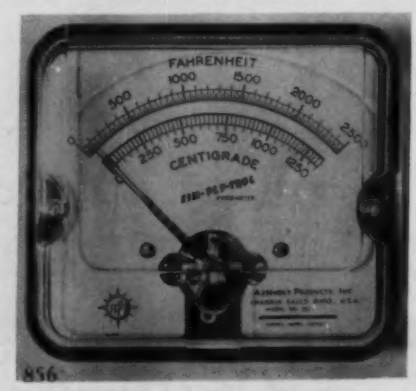
New "Type CAH" combination polyphase watthour and thermal demand meter, in a case no larger than standard

three-element watthour meter, is designed for light industrial and commercial loads where it is desired to incorporate a demand feature within the rate; minimizes space requirements and installation costs. New "CAH" line is available for three-phase three-wire; three-phase four-wire delta; open wye network; and three-phase four wire wye operation in the usual ratings of 5, 15, and 50 amperes at nominal application voltages of 120, 240, and 440; available in standardized A-base design. — *Westinghouse Electric Corp., P. O. Box 868, Pittsburgh 30, Pa.*

Mention No. 304 when filling out card

Temperature-calibrated Millivoltmeters for Thermocouples

New "Simplytrol Indicating Pyrometers" have dials calibrated in F. and C. Scales are over 3 inches long. Case



has one-piece crystal-clear plastic front. Instruments are available in several ranges up to 2500 F. and 1370 C. Four ohms per millivolt gives resistance of 212 ohms for 2500 F. Thermocouples do not need calibrated leads. Instruments are calibrated for 10 ohms external resistance (8 ohms for 500 degree range). A suitable resistance spool is provided for uncalibrated leads up to 15 feet long; is left out of circuit for longer leads, up to 100 feet. Internal construction features Alnico V magnets with sintered iron poles; extra flux for high-torque movement. Instruments are compensated for ambient temperature.—*Assembly Products, Inc., Main & Bell Streets, Chagrin Falls, Ohio.*

Mention No. 305 when filling out card

Alpha-particle Counter

New "Model D45 Methane Flow Proportional Counter" is designed for efficient detection of alpha particles: it counts alpha particles in the presence of high beta activity (billions per minute) with 50% geometry and low

coincidence losses. It has highly-polished cylindrical cathode; anode is 0.002-in. diam. tungsten wire mounted between glass insulators. Construction permits easy decontamination both inside and outside. Sample holder, designed for standard 1-inch diam. samples, has provisions for raising sample up into counting volume for improved geometry. Flow of methane gas through chamber is controlled.—*Nuclear Instrument and Chemical Corp., 223 West Erie Street, Chicago 10, Ill.*

Mention No. 306 when filling out card

Oscillo-record Camera Accessories

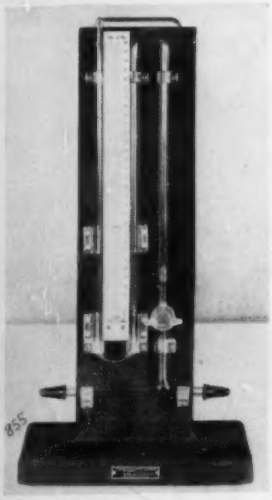
(1) New universal mount for maker's Oscillo-Record Camera is said to eliminate need for extra standard mounts when camera is used with several different oscilloscopes, since it supports camera and periscope without attachment to oscilloscope and entire assembly can therefore be moved as a unit from one instrument to another. Mount is adjustable in height to suit any standard oscilloscope. Fitted with shock-absorbing supports. Installation re-

quires no special tools or drilling. Especially recommended where a 1000-ft. external magazine is to be used with camera. (2) New adapter for mounting standard 35mm. 1000-ft. or 400-ft. magazine on Oscillo-Record Camera consists of mount casting and attaching bracket supporting motor and magnetic clutch for magazine take-up drive. (3) For viewing cathode-ray screen more or less continuously while recording, new Binocular Split Beam Viewer also is available. Special color selective filter permits simultaneous viewing and recording without danger of fogging film.—*Special Camera Div., Fairchild Camera and Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y.*

Mention No. 307 when filling out card

Direct-reading Manometer

New laboratory manometer provides direct readings of vacua in mm. and is said to be much more stable and less



fragile than ordinary manometer. Heavy glass tubes and stopcock are cushioned in "Plastubing" mounted on steel upright support and heavy base. Scale, easily read against black crackle finish of support, is calibrated from 0 to 300 mm. rather than having zero in middle of graduations as with conventional manometers. Plastic tube clips permit easy setting of scale.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 308 when filling out card

A-c. Power Supply

New "Type 4ST1A1" regulated power supply, continuously variable from 180 to 300 volts at 60 milliamperes, weighs 17.25 lbs., is intended primarily for use in laboratories, educational institutions,

and production test departments. A separate a-c. voltage of 6.3 volts at 2.5 amperes center-tapped can also be supplied by new unit, which delivers a constant output regardless of variations in line voltages or loads. A two-position switch enables operator to read either volts or milliamperes on a 4.5-in built-in instrument. He may also switch back and forth under load to monitor continuously. Unit can be operated grounded or ungrounded and ripple is less than 10 millivolts RMS.—*Specialty Div., General Electric Co., Electronics Park, Syracuse, N. Y.*

Mention No. 309 when filling out card

Power Supply, Amplifier and Oscillator

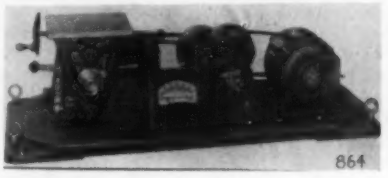
New line of simple, basic, unit-type laboratory instruments comprises units designed to be versatile in application and low in price. Three units are now available: (1) a 3-watt amplifier of 45-db gain, covering range from 20 cps.

to 200 kc; (2) an oscillator, with plug-in tuning units, operating from 400 cycles to 80 Mc.; and (3) a small, compact, a-c. power pack that plugs into either oscillator or amplifier. New instruments are particularly useful for student experiments because wiring is open and accessible, permitting student to modify circuit and study effect of modification on circuit performance. Illustration shows power supply and oscillator plugged together. Over-all dimensions of this combination are 16 x 5.88 x 6.5 inches.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 310 when filling out card

Fatigue Tester for Components

New "Model 10 VA Testing Machine" permits instrument, aircraft, automative and other parts, components and



assemblies up to 10 lbs. in weight to be readily subjected to vibration fatigue tests. Table (upper left in illustration) has 48 conveniently-spaced tapped holes. Vibration in simple harmonic motion is produced vertically. Acceleration is changed automatically and continuously and is indicated on a tachometer. Frequencies range from 10 to 55 cps.; can also be manually controlled.—*All American Tool & Mfg. Co., 1014 W. Fullerton Ave., Chicago 14, Ill.*

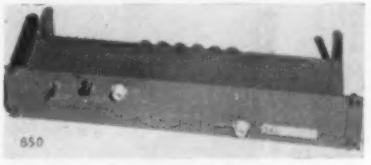
Mention No. 312 when filling out card

Packless Valves

CORRECTION: January issue, page 58, name of manufacturer should be "*Vacuum-Electronic Engineering Co., 316 Thirty-Seventh St., Brooklyn 32, N. Y.*"

Wide-band Chain Amplifier

New "Model 200A Chain Amplifier" is a traveling-wave amplifier with bandwidth of 200 Mc.; gain of 10 db per

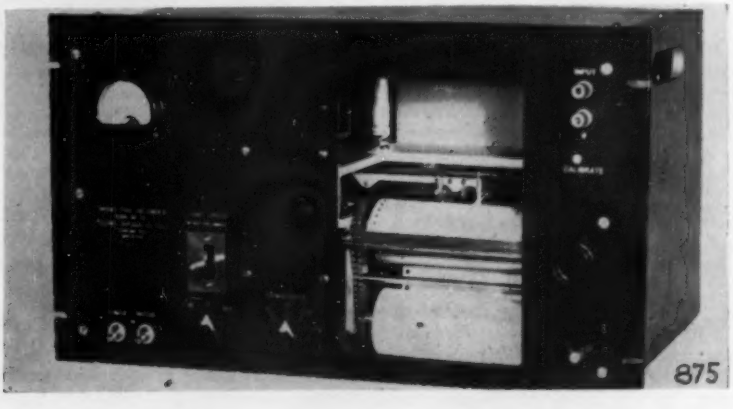


stage; useful range from 100 kc. to 200 Mc.; impedance level of 200 ohms; especially adapted for use in nuclear instrumentation, oscillography and general laboratory measurements. Trans-

Variable-chart-speed Recorder

New "Model FRA" recorder provides direct ink recordings of any rapidly- or slowly-changing measurable that can be converted to a-c. or d-c. voltage. Ranges can be selected and recorded on logarithmic or linear scale. Uses include recording vibrations, noises, strain and pressure, strength of field, etc. Available in 56 double chart-speed combinations from 45 in. per min. to 0.5 in. per hr. and for recording frequencies from 2 to 200,000 cps.—*Sound Apparatus Co., Stirling, N. J.*

Mention No. 311 when filling out card



mission characteristics is plus or minus 1.5 db from 100 kc. to 200 Mc. and standing-wave ratio is less than 1 db over this band. Phase shift substantially linear within pass-band, owing to mutual-inductance coupling between adjacent sections. Each stage has a tube complement of six 6AK5 tubes. Either one-stage or two-stage amplifiers are available in standard rack or table mounting.—*Spencer-Kennedy Labs., Inc., Dept. I, 186 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 313 when filling out card

Film Projection Comparator-Densitometer

New "Model 5400" Film Projection Comparator-Densitometer utilizes 35-mm. roll film rather than film plates, to provide greater uniformity of emulsion and simplify loading of both master and sample films. It has been developed

especially for reading and comparison of spectra photographed on any length of 35mm. spectrum analysis film. Sample and master films are held in two film stages, allowing separate or simultaneous motion along film by means of sprockets. Transverse movement is independent. A vernier adjustment permits exact positioning on screen scales for accurate measurement and close aligning of spectra. Master film is projected on lower half of screen; sample film on upper. Densitometric feature allows transmission readings to be made by mechanically scanning spectrum line with a 0.0007-in. slit in near contact with emulsion side, so that all scattered light produced by projection systems is eliminated and accurate film calibration results. Light passing through slit is picked up by a phototube; output is amplified by a bridge-circuit amplifier which actuates a quick-reading galvanometer whose scale reading is projected on screen near image of line being measured. Hence, both qualitative and quantitative analyses are greatly speeded. — *Applied Research Laboratories, 4336 San Fernando Road, Glendale 4, Calif.*

Mention No. 314 when filling out card

Electrical Thermometer

New "Model 918" thermometer, designed particularly for applications where remote indications are necessary, employs a resistor bulb readily placed in tanks, grain bins, machines, etc., with indicating instrument at a distance. With selector switch and multiple bulbs, number of temperature measurements are possible while using one indicator. Indicator is ratio-type instrument with a scale over 5 in. long. It is for use on 100-130 volts, 50-60 cycles a.c. and is not affected by normal line voltage variation. It can also be supplied for use on d.c.—*Weston Electrical Instrument Corp., 617 Frelinghuysen Ave., Newark 5, N. J.*

Mention No. 315 when filling out card

Storage Battery Tester

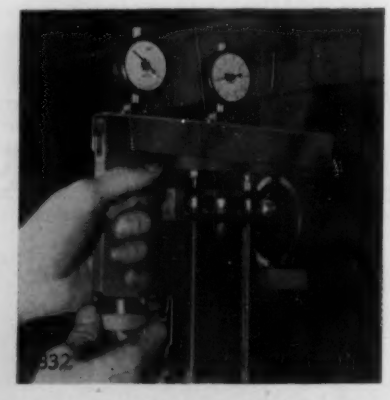
New "Model P-60 Chargicator" indicates electrically equivalent gravity of lead-acid storage batteries, regardless

of size or voltage. Said to be four times as accurate as conventional hydrometer. Probe-type instrument (illustrated) provides instant measurements without load on battery. Instrument indicates how fast battery may be safely charged, also shows percentage of charge and charging danger. Dial is large for easy reading and case is Bakelite.—*Hickok Electrical Instrument Co., 10519 Dupont Ave., Cleveland 8, Ohio.*

Mention No. 316 when filling out card

Portable Hardness Tester

New portable hardness tester for Rockwell readings weighs only 3 lbs. 6 oz. and has convenient carrying case.



Tester is said to be comparable in accuracy to bench type testers.—*Riehle Testing Machines Div., American Machine and Metals, Inc., East Moline, Ill.*

Mention No. 317 when filling out card

High-altitude Aircraft D-c. Relay

New "Type CX3554" hermetically-sealed miniature d-c. relay meets extreme conditions of modern high-altitude and jet-propelled aircraft. Special aviation design features include shock resistance up to 50 G's; vibration resistance better than 10 G's; high-speed opening and closing without contact bounce; and reliable operation over an ambient temperature range from minus 75 C. to plus 200 C. and at altitudes to 70,000 feet. S-p. d-t. contacts nominally rated at 2 amperes withstand inrushes of 12 amperes at 26.5 volts d.c. The coil is rated at 26.5 volts d.c. with an operating range of 18-32 volts d.c. Of cylindrical shape with mounting "feet," new relay is approx. 1.75 in. high including terminals, with a flange diameter of 1.04 in. and 1.375 in. between mounting hole centers.—*Struthers-Dunn, Inc., 150 N. 13th St., Philadelphia 7, Penna.*

Mention No. 318 when filling out card

Electrodeposition Analyzer

New "Electrograph" is said to be pioneering instrument with potential applications in qualitative and quantitative analyses of metals and metallic alloys; provides unmistakable spot color reactions for identifying unknown con-

stituents. It transfers electrically a few micrograms of sample onto previously-prepared bibulous paper or gelatin surface. Standard qualitative spot tests then indicate presence of elements. Instrument includes separate power source with batteries, electrode potential and polarity controls, and current-voltage indicators. Sample is held under controlled pressure against test paper. Current is applied usually for 20 to 30 seconds. Color intensity varies both with time of "exposure" and with concentration of element in sample. Uses include detection of pinholes in electroplated metals, detection of lead-containing brass, observation of homogeneity, etc. Exact pattern of molecular composition in sample is "pictured" on test paper, indicating distribution and quantitative amount.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 319 when filling out card

Logarithmic Attenuator

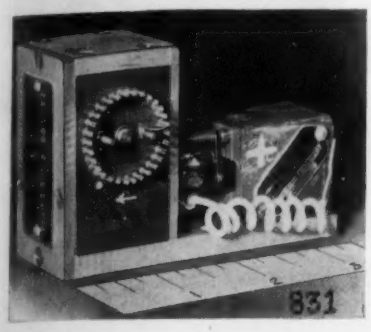
New "Logaten" attenuator is essentially a network of non-linear circuit elements adjusted to give output voltages accurately proportional to logarithm of input voltage. Components are inert and no external power is required. Equally effective from d.c. to 500 kc. New unit permits use of VTVM as decibel meter; extends dynamic range of oscilloscope for reverberation studies; for multiplying voltages, and for compressing signals of excessive dynamic

range. "Model 510A" has banana plug while "Model 510B" has octal socket. Available also with special exponential curves.—*Kalbfell Labs.*, 1076 *Morena Blvd., San Diego* 10, *Calif.*

Mention No. 320 when filling out card

Multi-channel Mechanical Switch

New subminiature multi-channel mechanical switch is furnished in two- or four-pole models, each pole having

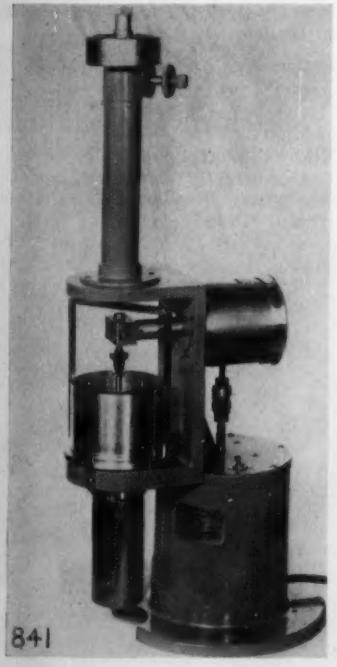


15 channels. Sampling rates up to 3,000 per minute can be obtained. Handles relatively large current (compared to electrical counterpart). Switch has been used in guided-missile, aircraft and balloon applications.—*Applied Science Corp., P. O. Box* 44, *Princeton, N. J.*

Mention No. 321 when filling out card

Viscosimeter

New "Texaco Viscosimeter" is for measuring viscosity in plastic fluids and thixtropic suspensions, or any other non-Newtonian fluid, in which viscosity varies both with rate of shear and with time. Features: (1) wide range of fixed



speeds; (2) stroboscopic arrangement for checking rotor speeds; (3) high velocities, to allow fluids to reach equilibrium viscosity; (4) continuous recording for any length of time; (5) completely friction-free torque measurement; (6) oil damping which insures steady readings on heavy fluids; (7) ample power to break jells, enabl-

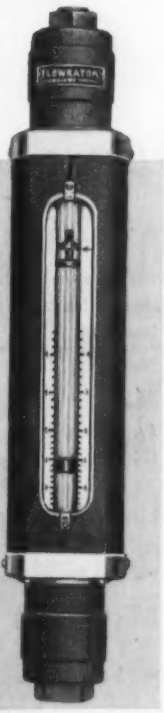
VISCOSITY MEASUREMENT

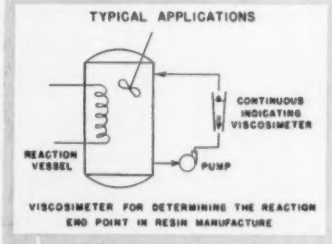
CONTINUOUSLY AUTOMATICALLY

(and with automatic control of the viscosity, if desired) RIGHT IN THE PIPE LINE, WITHOUT WITHDRAWAL OF FLUID SAMPLES, WITHOUT STOP-WATCH READINGS OF EFFLUX TIMES

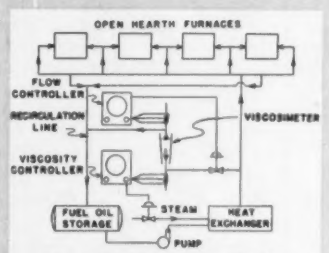
NOW AN ACCOMPLISHED FACT

Viscosimeters have graduated from the class of laboratory test instruments to full-fledged industrial instruments which perform their function without manipulation by an operator, just as temperature, pressure, flow and level instruments have been doing for many years.





VISCOSIMETER FOR DETERMINING THE REACTION END POINT IN RESIN MANUFACTURE



FLOW DIAGRAM FOR VISCOSITY CONTROL OF OPEN HEARTH FUEL OIL

PRINCIPLE OF OPERATION

Continuous viscosimetry has been accomplished by utilizing one of the unique properties of the F & P FLOWRATOR meter (formerly rotameter): ability to make metering floats either viscosity sensitive or viscosity immune. Into one FLOWRATOR are placed two metering floats, the one so shaped that it is very viscosity sensitive, the other one with the patented F & P viscosity immune shape. When fluid flows upward through the tapered metering tube both floats will, of course, rise in the normal manner. However, the elevation of the one float will be relatively slight, since it is produced solely as a function of fluid flow rate. The other float elevation will be much greater since it is a function both of viscous drag and flow rate. The space increment thus created between the two floats is a direct measure of viscosity. By selecting any particular flow rate which will give a convenient elevation of the one float to serve as a reference line, the other float elevation may be marked as viscosity graduations in terms of centipoises, centistokes, S.S.U. or any other desired units. Viscosity measurement all the way from .0008 to 800,000 centipoises is now possible.

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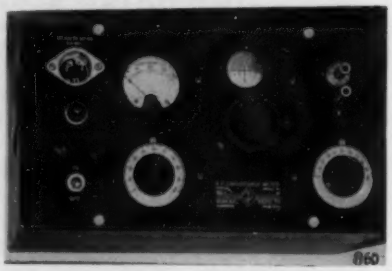
ing accurate determination of jell strength; (8) agitation of entire sample; (9) special rotor and cup for laminar flow studies; (10) elimination of channeling; (11) use with various cups and rotors.—(Under agreement with The Texas Co.) *Southwestern Industrial Electronic Co., 2831 Post Oak Road, Houston, Texas.*

Mention No. 322 when filling out card

R-f. Capacitance Meter

New "Type 1612-A R-F Capacitance Meter" is designed for rapidly measuring and testing small capacitors (up to 1200 micromicrofarads) as used in r-f. equipment. It is equally useful in laboratory and in production testing; for



latter use a simple test jig can be devised to facilitate connections. Measurement is made (at 1-Mc. frequency) by a substitution method in which capacitance of a calibrated air capacitor is reduced to re-establish resonance after an unknown capacitor is connected. Resonance is indicated by maximum deflection of indicator. Maximum deflection can be also used as an indication of loss, and hence as a basis for rejection of high-loss capacitors when compared to a standard sample. Two ranges are provided and range switching is accomplished automatically as dial is rotated. Instrument is 12 in. wide, weighs 11 lbs., operates from a 115-volt power line, either a-c. or d-c.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 323 when filling out card

Laboratory Refrigerator

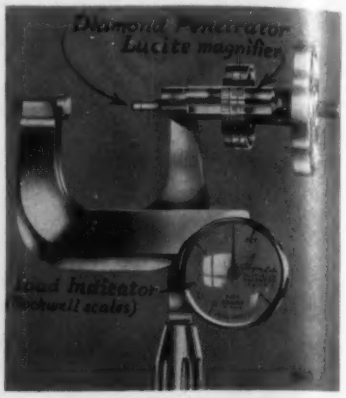
New refrigerator unit of 4 cu. ft. capacity has been added to maker's line of 14 previously available units of

laboratory furniture. It incorporates standard G-E cooling unit and is furnished with or without "Kemrock" top and reagent shelf. When installed with top and shelf, refrigerator unit is 36 in. high, making continuous working surface with other standard units.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 324 when filling out card

Portable Hardness Tester

New "Model 2" portable hardness tester is similar to previous models (described in detail in our issues of



Jan. 1947, p. 70; March 1947, p. 222 and Nov. 1947, p. 1037); has deeper throat for testing parts up to 2 in. and for testing farther from edge of sheet stock.—*Ames Precision Machine Works, 131 Lexington St., Waltham 54, Mass.*

Mention No. 325 when filling out card

High-voltage Selenium Rectifier

New "Model SE8L" high voltage selenium rectifier, completely sealed, measures 0.25 in. in diameter and is available in lengths up to 3 in. Rectifier has two tinned pigtail connections and is rated up to 3,000 volts peak inverse at 1.5 milliamps. d. c. It can be arranged in a series or in voltage multiplier circuits for higher voltage requirements. Designed for portable or sealed equipment requiring high voltage d.c. —*Bradley Labs., Inc., 82 Meadow St., New Haven, Conn.*

Mention No. 326 when filling out card

Microwave Power Meter

New "430A Microwave Power Meter" indicates directly, on a 4" square instrument, power developed in a standard barreter. No calculation or knob-twisting is necessary once range selection and zero set are made. It is automati-

cally self-balancing, and may be used over any frequency, depending on associated barreter and mount. It consists of an a-c. bridge, one arm of which is a barreter. Bridge is in balance with zero r-f. power in barreter. As r-f. power is applied to barreter, an equivalent a-c. (audio) power is automatically removed. Thus, bridge remains in bal-

ance. VTVM (calibrated in milliwatts) gives a direct indication of r-f. power in barreter, is also calibrated in dbm (0 dbm equals 0.001 watt) so that continuous readings are available from minus 20 dbm to plus 10 dbm. Range may be extended by use of attenuators or directional couplers.—*Hewlett Packard Co., 395 Page Mill Road, Palo Alto, Calif.*

Mention No. 327 when filling out card

Magnetic Reset Counter

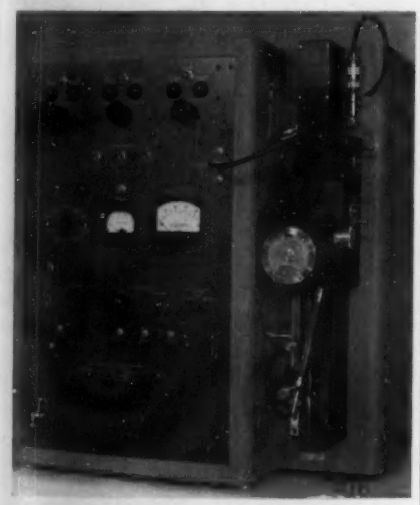
New magnetic counter is of smaller size for built-in installations, is said to afford durability and accuracy because

it has fewer working parts. Especially adapted to remote-indication from plant to office. Counter features 6 large figures, in large windows. "Model 1205" is for a.c. only; "Model 1248" is for d.c. only. — *Veeder-Root Inc., Hartford 2, Conn.*

Mention No. 328 when filling out card

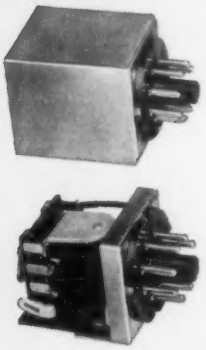
Microwave Dielectrometer

New Microwave Dielectrometer, for measuring dielectric constant and loss of materials at nominal frequencies from 1000 to 9000 Mc. consists of a slotted wave guide, precision traveling probe, modulated klystron oscillators, probe output amplifier, associated power supplies and equipment. Sample is in-



serted ahead of a short-circuiting plug and effect of this arrangement on standing-wave pattern in guide provides data for calculating dielectric constant and loss of material. At 1000 and 3000 Mc. wave guide is used as a coaxial line;

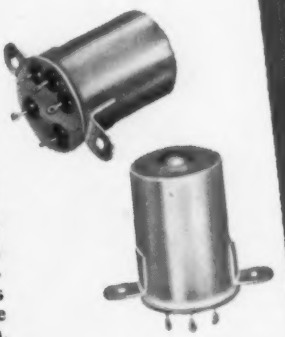
3 IMPORTANT NEW Relay Developments



NEW!...TINY OCTAL BASE RELAYS for AC, DC or half-wave rectified AC

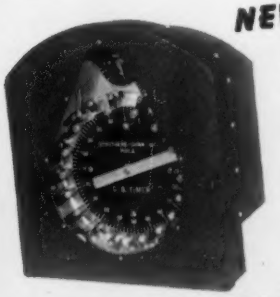
TYPE 118XBX: Available in either open or metal-enclosed types as illustrated, also hermetically sealed. Highly sensitive on DC. DP-DT contacts rated 2 amps. at 115 V. AC. DC operating power is .15 watts with maximum coil resistance of 2,200 ohms. Write for Bulletin 2400.

NEW!...HERMETICALLY SEALED DC RELAYS FOR HIGH-ALTITUDE AVIATION



These little CX3554 Relays are insensitive to humidity changes and capable of operation at 70,000 feet. Features include shock resistance to 50 G's; vibration resistance better than 10 G's; high-speed operation without contact bounce, and reliability over an ambient range of −75° C. to +200° C. SP-DT contacts nominally rated 2 amps. withstand inrushes of 12 amps. at 26.5 V. DC. Coil is rated 26.5 V. DC with operating range of 18/32 V. DC. Write for Bulletin 2410.

NEW!...MONEY-SAVER FOR TIMING CONTINUOUS PROCESS WORK



Stepless, wide-speed range. Complete timing reliability

Besides eliminating the need for numerous cascaded timers, the new Struthers-Dunn DB Timer usually requires much less auxiliary control equipment. An entire process combining many operations can quickly be set up on a single dial. Total time cycle adjustments as well as the timing of individual periods are easily made. Write for DB Timer Bulletin 7110.

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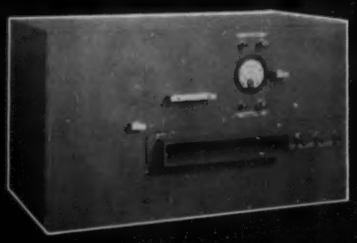

— Vibrations —
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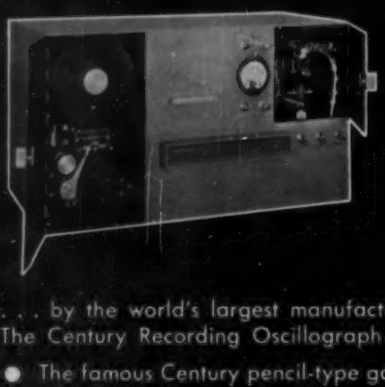

— Pressures —
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- The famous Century pencil-type galvanometers, 4 to 28 hermetically sealed elements — wide selection of natural frequencies to 5,000 cycles per second — high factors of sensitivity and balance.
- Governor controlled paper drive motor adjustable ± 20% fixed speed — gear shift transmissions with automatic lamp intensity device.
- Temperature compensated tuning fork — discharge lamp imposing sharply defined .01 second lines with heavy .1 second lines.
- Daylight loading 200 ft. storage and takeup magazines — accommodate 2" to 8" paper widths.
- Available with following optional features:
  Paper speeds to 50 inches per second — Automatic record length control — Automatic record numbering — Sweep scanning — Footage indicator — Trace identification — Remote control — 12-volt d.c., 24-volt d.c., or 110-volt a.c. operation.

Write for Catalog No. 101 — A, descriptive of this and other models of Oscillographs.

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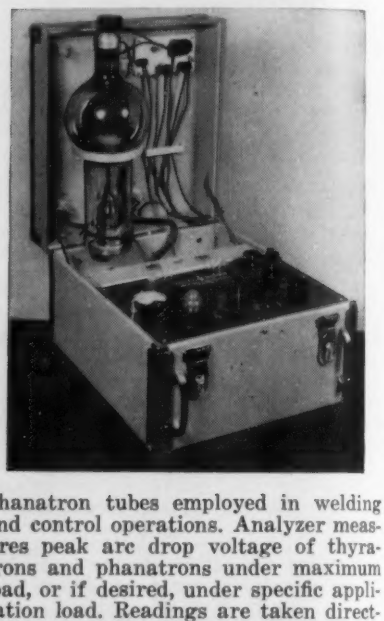
and at 9000 Mc. either as a circular pipe or as a coaxial line. Solids are measured directly in wave guide in form of cylindrical samples 1 in. diameter and about 1 to 2 in. long with a 0.375 in. hole coaxial with outer surface except when guide is operated as a circular pipe at 9000 Mc. Auxiliary sample holders can be used for measuring liquid samples, and also for measurements at controlled high and low temperatures. Range of measurement of dielectric constant extends from 1 to 100; of dissipation factor from 0.0001 to 1.0. Accuracy of 1 to 2 percent can be achieved.—*General Research Labs., Inc., Red Wing, Minn.*

Mention No. 329 when filling out card

Tube Analyzer

New "Type YTW-3" vacuum tube analyzer supersedes maker's "Type TT-1" for use with thyratron and

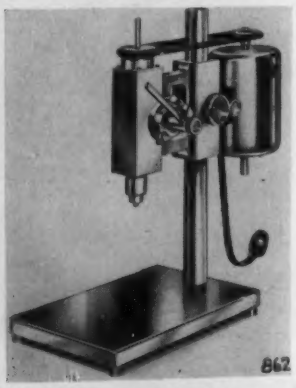


phanatron tubes employed in welding and control operations. Analyzer measures peak arc drop voltage of thyratrons and phanatrons under maximum load, or if desired, under specific application load. Readings are taken directly from large dial, which controls slide-back type voltmeter.—*Specialty Div., General Electric Co., Electronics Park, Syracuse, N. Y.*

Mention No. 330 when filling out card

Instrument-shop Drill Press

New precision drill press uses a standard Jacobs chuck, takes drills from No. 0 to 0.1563 in. Adjustable



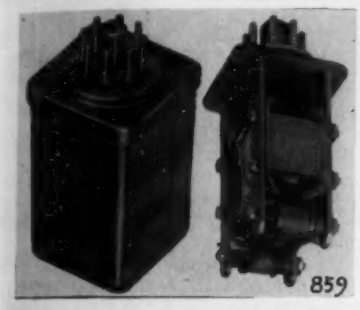
clearance, chuck to fixed table base, is 0-7 in. Spindle feed of 1 in. has solid, sensitive feel. Coarse and fine adjustments on spindle-stop permit precise

work. Foot-operated rheostat control permits speed to be adjusted from 6000 r.p.m. down to zero. Unit employs easily-detached 0.1-hp. double-sealed ball-bearing a-c.-d-c. motor. Over-all height is 12 in.; weight is 18 lbs. with motor. Available complete, or without motor and foot control.—*Cobb Precision Co., 6656 Lexington Ave., Hollywood 38, Calif.*

Mention No. 331 when filling out card

Polarized Relay for High-speed Telegraphy

New "Type 7 JOZ" is a sensitive s-p. d-t. polarized relay developed under a Signal Corps contract calling for miniaturization and improvement of existing types of high-speed telegraph keying relays. It is hermetically sealed,



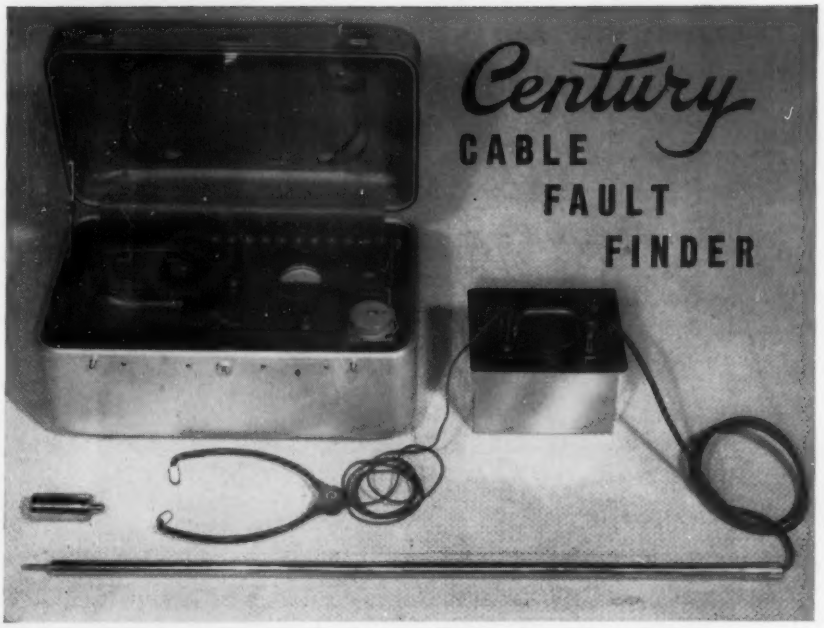
fits standard octal tube socket, is serviceable up to 250 wpm. Contacting is essentially bounce-free and characteristic distortion is entirely absent except at highest speeds. Transfer time depends on driving circuit but is less than 1 millisecond. Windings available include usual matched pair with resistance around 150 ohms each, other combinations up to 14,000 ohms in a single winding. Standard twin 150-ohm model operates satisfactorily on 5-ma. reversals in one winding, and "just trips" at approx. 1 ma.—*Sigma Instruments, Inc., 70 Ceylon Street, Boston, Mass.*

Mention No. 332 when filling out card

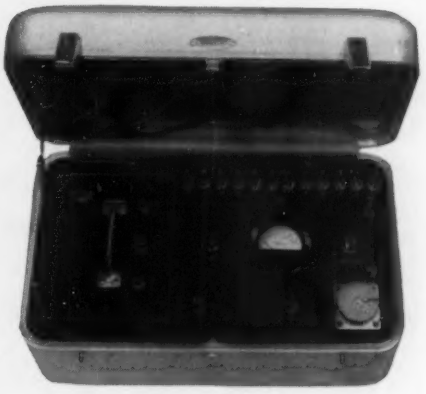
Combustible-gas Alarm

New "Explosilite" flashes a brilliant red signal light when a dangerous concentration of combustible gas is pres-

ent; is approved by U. S. Bureau of Mines for use in atmospheres contaminated with methane; may be preset for a specific concentration of natural gas or petroleum vapors. It operates automatically, continuously sampling air and requiring no training or skill to use. An Edison nickel-iron battery runs it



The Century Cable Fault Finder has been especially designed to meet the rigid requirements of multi-conductor cable maintenance. The unit offers pin-point location of either "shorts" or "opens" in unshielded cable and "shorts" through non-magnetic shielded cable.



The entire unit, including dual signal generator and receiver with accessories, is contained in one water-tight aluminum carrying case.

The dual signal generator contains a 27-pin Cannon connector. Special adapters to fit other connectors are available. Switches at top of instruments select the pair of wires on which signals are to be impressed. Positive identification of wires in question is assured by a built-in Ohmmeter.

In checking a pair of wires, the generator places an 800 c.p.s. signal on one wire and a 1000 c.p.s. signal on the other. If wires are intact, the beat frequency of the two are received. When one wire is broken, the pitch of the received signal instantly changes to either 800 to 1000 c.p.s. The use of two signals requires only one trip down the cable to locate the open circuit.

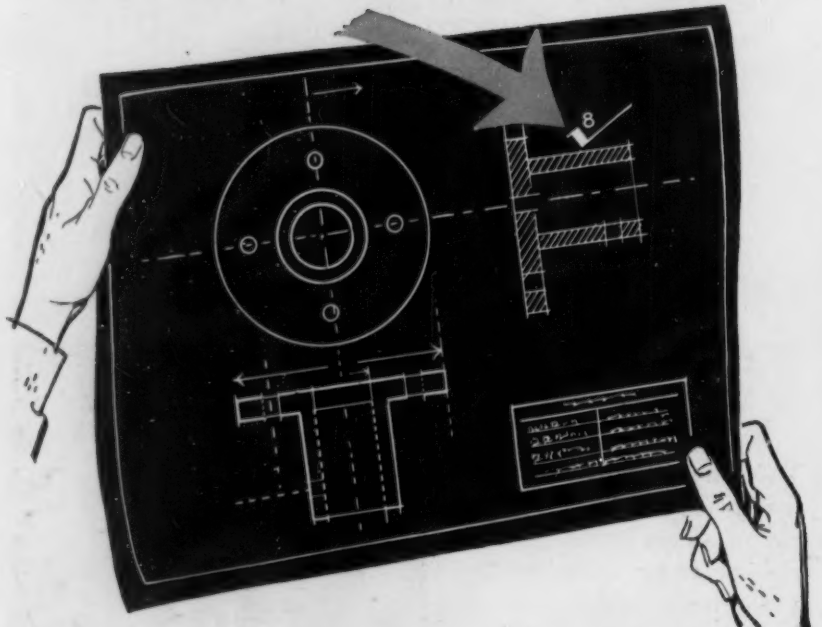
Signals are produced electronically and power is supplied by portable batteries within each unit.

Total weight of the Cable Fault Finder . . . approximately 19 lbs.

Century GEOPHYSICAL CORPORATION
TULSA, OKLAHOMA
149 Broadway New York

Are you sure you are meeting print specifications on

SURFACE FINISH?



Avoid guesswork and approximations
Be sure with the SURFACE ANALYZER*

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- Human error is eliminated by accurate power-driven pickup, chart record and calibration in terms of an absolute standard.
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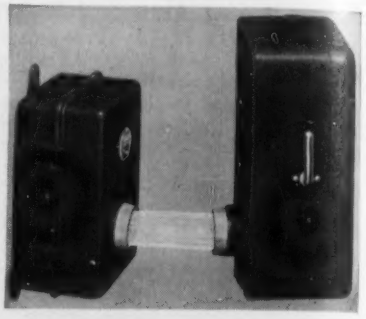
for 18 to 20 hours. Tamper-proof: can be opened for adjustment only by authorized personnel equipped with a special magnet.—*Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh 8, Pa.*

Mention No. 333 when filling out card

Photoelectric Smoke Indicator

New "Type A20C-1" smoke indicator consists of a photoelectric relay and a light source which can be mounted in

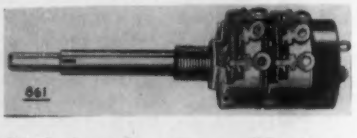


flue or breeching to signal when smoke density reaches pre-selected level. Supplementary equipment includes bell alarm and recorder. Instrument has sensitivity adjustment to permit signalling at any desired smoke intensity. Operates on 115-volt a.c.—*Photoswitch, Inc., 77 Broadway, Cambridge 42, Mass.*

Mention No. 334 when filling out card

Dual Variable Resistor

New "Midgetrol Dual" is a compact dual variable resistor for television and other applications. Its small diameter

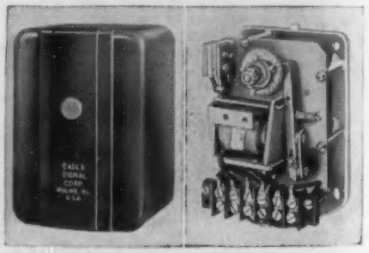


(0.94 in.) makes it possible to move several key TV adjustments from rear of chassis to front: eight single controls now required can be changed to four "Midgetrol Duals." New unit's characteristics suggest possibilities of applications in other fields than TV. —*P. R. Mallory & Co., Inc., 3029 E. Washington St., Indianapolis 6, Ind.*

Mention No. 335 when filling out card

Automatic Timer

New "Timoflex" delay relay provides timed closing or opening of electrical circuits; is available in three basic



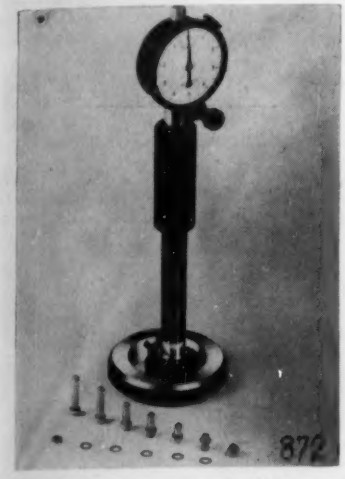
forms for industrial applications. One form starts timing when pilot switch is closed, another when pilot switch opens and a third when a push button is closed momentarily. Slow-speed synchronous

motor has a separate reset coil to release timing mechanisms. Simple construction: only two rotating parts in addition to the motor. Four standard timing scales: 55 seconds; 5.5, 27.5 or 55 minutes.—*Eagle Signal Corp., Moline, Illinois.*

Mention No. 336 when filling out card

Dial-bore Gages

New model of "Nilco" dial bore gages can be set much more quickly and provides greater accuracy for longer time than previous models. Non-skilled workers can use, assemble, clean or replace parts. Available in five sizes from 0.875

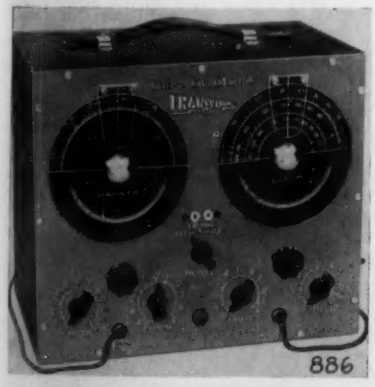


to 12 in. Can be adapted with any other American gage design indicators. Range extension consists of extension, washers and nut for quick setting; centralizing plunger assures accurate centering, and tension is adjustable for different surfaces. Direct setting to gage blocks can be made for short runs.—*Nilsson Gage Co., Inc., 2A Lake St., Poughkeepsie, N. Y.*

Mention No. 337 when filling out card

Sweep Signal Generator

"New "Model SG" sweep signal generator for television and FM features complete frequency coverage from 0-227



Mc. with no band switching, sweep width from 0-12 Mc. completely variable, and accurately calibrated built-in marker generator. Dial is calibrated in frequency; crystal-controlled output makes possible any crystal-controlled frequency from 5-230 Mc. Output impedances is 5-125 ohms. Unmodulated RF signal provides marker pips simulta-

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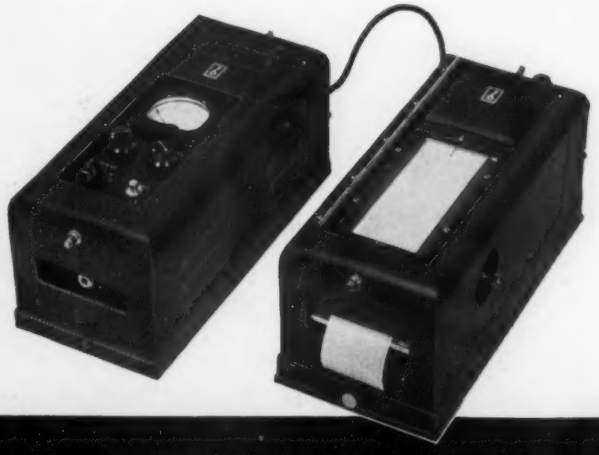

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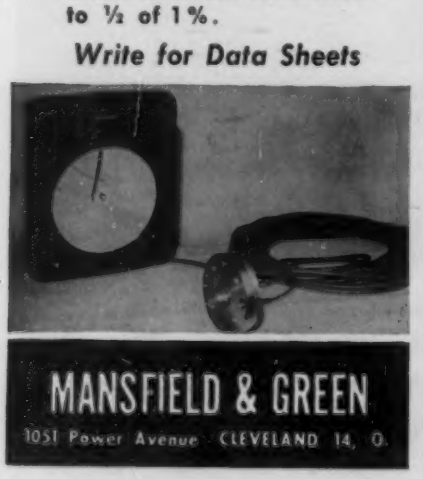


MANSFIELD & GREEN

1051 Power Avenue CLEVELAND 14, O.

neously with main variable oscillator. Power supply required: 105-125 volts, 60 cycles. Power consumption: 35 watts at 115 volts.—*Transvision, Inc., New Rochelle, N. Y.*

Mention No. 338 when filling out card

Voltage Reference for CROs

New "Model G-1402 Baseliner" provides a continuous reference of zero voltage on cathode-ray oscilloscope screen; permits gain-frequency measurements and enhances accuracy in test

Fig.1 866

and measurement work; makes new techniques possible. Instrument comprises a high-speed switch having extremely low contact resistance and fast change-over time, together with associated tubes and circuits to provide power supply and to provide switch operation where "on" time is controllable in frequency, phase and duration. Technique of transferring a d-c. voltage through an a-c. R-C-coupled amplifier is brought out by simplified diagram, Fig. 2. When S1 is closed, C1 charges

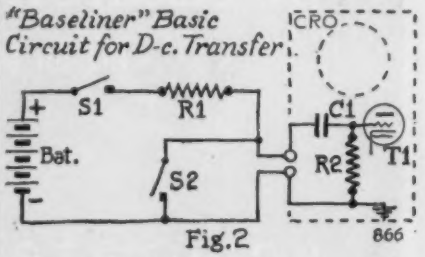


Fig.2 866

through R1 and R2, grid of T1 goes positive and spot moves up-screen. When C1 is fully charged, current flow ceases, grid returns to its static value, spot returns to its former position and nothing further happens so long as conditions remain unchanged. Now, if S2 is momentarily closed, C1 discharges through R2 while battery is protected by R1; grid of T1 goes negative and spot moves down-screen. As soon as S2 is released, C1 begins to charge and cycle is repeated. Thus, spot displacement is proportional to battery voltage as C1 has been alternately charged to full voltage and discharged to zero. If S2 is operated rapidly and no time base is used on CRO, result will be two spots, one above other with a faint vertical trace between; if time base is used, pattern will be a square wave of fundamental frequency equal to switch rate and length proportional to "on" time. If an incremental voltage (such as obtained across a diode load) is substituted for batteries, varying charge on C1 during S2 "off" time provides for viewing a-c. component on upper trace while lower trace (produced during S2 "on" time) provides constant reference of zero voltage. An example (response curve of a TV i-f. amplifier) is shown in Fig. 3. Instrument is housed in 8 x

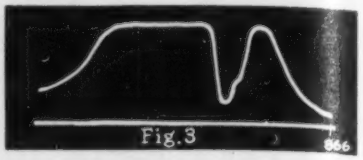


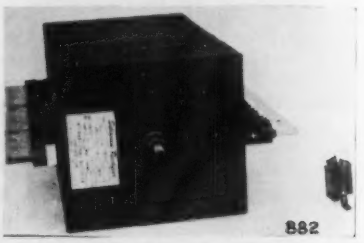
Fig.3 866

10 x 8 inch sloping-front cabinet, operates on 105-125-volt 50-60-cycle a.c.; consumes 35 watts. For maximum switch life, voltage across open contacts should not exceed 350 volts and reactive energy storage to be switched without contact protection should not exceed 40 microjoules.—*Globe Products Corp., 870 Maplewood Ave., Bridgeport 5, Conn.*

Mention No. 339 when filling out card

Selenium Rectifiers

New selenium rectifier stack features special moisture-proof finish capable of withstanding high humidity, fungicidal



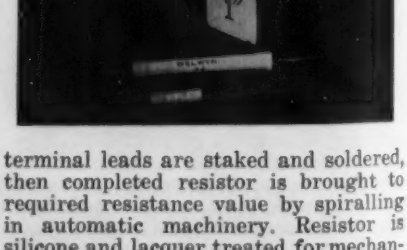
882

corrosion and salt spray for periods up to 200 hrs. Rectifier plates are made in six different sizes ranging from 1.25 x 1.25 in. to 6.25 x 7.25 in., latter size said to be largest selenium rectifier plate commercially available. D-c. power requirements from 2 volts and 150 ma. to 5000 volts and 10,000 amps. (and above) can be handled with efficiencies varying from 65 up to 85 percent depending upon circuit employed. Each plate is rated at 26 volts rms. inverse voltage. Rectifiers are capable of withstanding 1000 percent overload for intermittent service.—*International Rectifier Corp., 6809 S. Victoria Ave., Los Angeles 43, Calif.*

Mention No. 340 when filling out card

Carbon Resistors

New carbon resistor of "cracked carbon" process of English manufacture, is a homogeneous film of pure carbon deposited on a porcelain tube. After aging, carefully-fitted turned-brass end caps are applied, into which



terminal leads are staked and soldered, then completed resistor is brought to required resistance value by spiralling in automatic machinery. Resistor is silicone and lacquer treated for mechanical and moisture protection. This tech-

nique is said to assure high stability and adherence to 1 percent tolerances. Also available in 2 and 5 percent tolerances, and in sizes of 0.25 to 2 watts capacity. Resistor will dissipate full power rating in ambient temperatures of 100 deg. C. Temperature coefficient of resistance of cracked carbon is of order of 0.02 percent per deg. C. Voltage coefficient of resistance is of order of 0.002 percent of resistance value, per volt applied. Resistors are offered in range from 100 ohms to 50 M and wider ranges in 5 percent tolerance—*Welwyn Electronic Components, Inc.*, 234 *E. 46th St., New York* 17, *N. Y.*

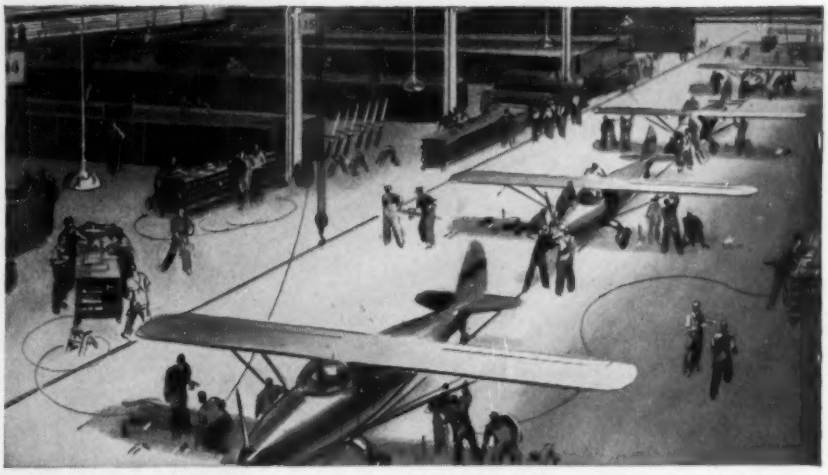
Mention No. 341 when filling out card

Color Densitometer

New "Model 1" color densitometer does not require a "warm-up" period, operates without glare so that it is easy to locate desired section of negative to be sampled. It enables worker to make either black-and-white or color prints

on a truly scientific basis by providing an exact check on exposure, contrast, required contrast grade of paper, and negative densities. Densities from 0.0 to 3.0 can be read directly from scale; when a supplementary neutral density filter is employed, densities up to 4.0 can be read. Scale divisions are uniformly spaced throughout entire range. Densities are measured against a unique optical wedge made of a special plastic in which are suspended minute graphite particles. Comparison is obtained by use of two independent light sources—two General Electric miniature bayonet-type lamps having a rating of 0.60 amps. and 5.8 volts. Light from one lamp passes through sample; light from other lamp passes through wedge. Wedge is rotated until intensities match: reading is then taken from circular scale (attached to wedge) graduated from 0.0 to 3.0 in graduations of 0.05. For higher readings with neutral density filter, density of filter is added. For precision in reading from a small section of negative, new densitometer has been designed to measure from an area no greater than 1.25 mm. in diameter. Scanning head is so located that an area can be read in center of an 8 × 10 in. color transparency or negative. When scanning assembly is lifted, brightness of lamps is automatically reduced to prevent glare. Color filters are provided to make it easy to read densities in a color transparency when no gray scale is included in subject area: red Kodak Wratten No. 70,

Seven new planes completed ...at a cost of $4.30!



New planes can't fly without control cable, and this manufacturer needed some —fast. He got it the same way he regularly gets many supplies and parts—by Air Express. Ordered in A.M., delivered to plant same day. 500 miles, 28 lbs., Air Express charge only $4.30. So production continued without a break.

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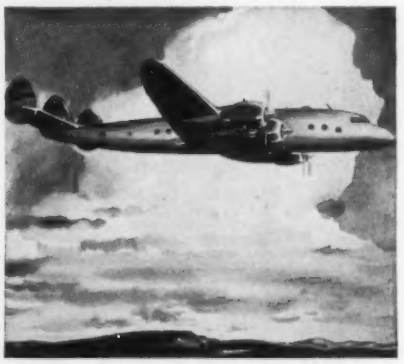

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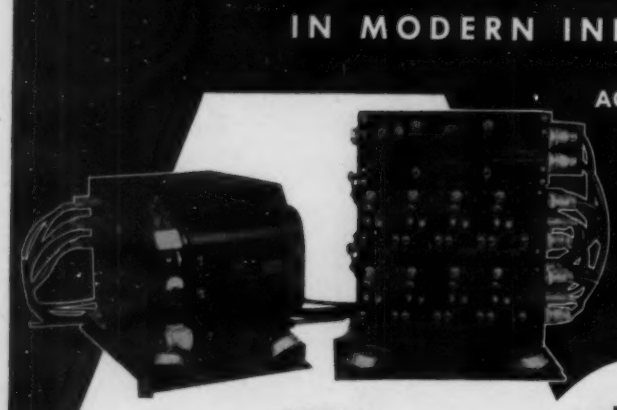

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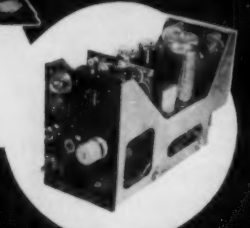

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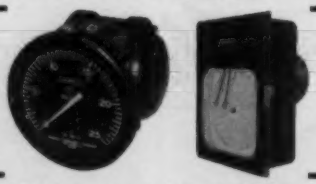

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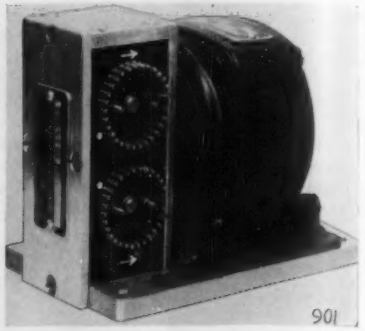
green No. 74, and blue No. 39A. Other filters for special applications may be substituted for those furnished. A blank space is provided on filter holder for use with black-and-white work. Instrument operates only on 110-125 volt, 50-60 cycle a.c.—*Eastman Kodak Co., Rochester 4, N. Y.*

Mention No. 342 when filling out card

Multi-channel Switch

New multi-channel switch driven by 60-cycle synchronous motor is said to assure constant sampling rates and



convenient use of a-c. line voltage sources whose frequencies are automatically synchronized with sampling operation. Model illustrated is 4-pole type measuring 2 x 3 x 4 in. with 30 contacts per pole. Wiper is of shorting type for flexibility. Standard models have sampling rates from 90 to 720 rpm. Switches facilitate investigation of large number of separate magnitudes or of a single magnitude under a number of different conditions. Useful for telemetering, display of characteristic curves and multi-channel voltage comparisons. Addition of switch rotor permits synchronization of electrical operations with mechanical motion.—*Applied Science Corp., P. O. Box 44, Princeton, N. J.*

Mention No. 343 when filling out card

Voltage Regulator

New "Stabiline Type IE51002" voltage regulator has a rated output of 0 to 250 volt-amps., is completely electrical in operation; has no moving parts, is said to deliver constant output voltage regardless of variations in input voltage or load current, and maximum change in output voltage due to either of these variations is stated as not exceeding plus or minus 0.25 per

cent. For input changes only, change in output voltage is said not to exceed plus or minus 0.1 percent, and speed of correction is said to be from 3 to 6 cycles. "Type IE51002" is rated at 95 to 135 volts input; output is adjustable between 110 and 120 volts; rated output being 0 to 250 volt-amps. Load power factor range is 0.5 lagging to 0.9 leading; wave-form distortion is claimed never to exceed 3 percent. Stabilization is stated as plus or minus 0.1 volts of pre-set value, regulation as plus or minus 0.15 volts. Standardization of tubes is said to be one innovation.—*Superior Electric Co., 30 Hannon Ave., Bristol, Conn.*

Mention No. 344 when filling out card

FM-TV Noise Meter

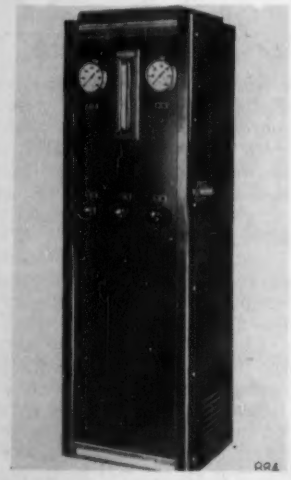
New "Mega-node" is said to provide for first time means of measuring noise figure of FM and TV receivers. Instru-

ment is calibrated source of random noises covering range of 0 to 220 Mc. Output impedance of 50 to infinity ohms provided by front-panel switch. Noise figure ranges of 0 to 17 db at 50 ohms, 0 to 23 db at 300 ohms are available. Linear scale is graduated for direct readings in db.—*Kay Electric Co., Pine Brook, N. J.*

Mention No. 345 when filling out card

Chlorine Dispenser

New "Rato-Chlor" chlorine dispenser is assembled from standard components each of which is particularly designed for chlorine service. It is a "dry vacuum" chlorine dispenser which uses no water seals, bell jars, poppets or simi-



lar devices. Chlorine from cylinder, drum or tank-car is filtered first to remove gum-forming hydrocarbon impurities, then delivered to "Rato-Chlor" unit at a controlled pressure of minus 20 in. W.C. Flow rate is set by pack-

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less needle-type regulating valve and measured by maker's "Flowrator" meter calibrated to indicate lbs. per day of chlorine vapor. Differential pressure regulating valve completes flow control element that maintains pre-set flow-rate. Vacuum is created by an ejector and kept uniform by a vacuum regulating valve. Safety feature is a vacuum-operated shut-off valve which automatically interrupts flow of chlorine in event of leakage. Chlorine flow is also interrupted when ejector supply water is shut off. Meter can be equipped with recording or totalizing accessories. Dispensers are produced in 17 standard sizes ranging from a minimum capacity of 10 lbs. per day to a maximum capacity of 7500 lbs. per day.—*Fischer & Porter Co., Hatboro, Penna.*

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Weld-time Meter

New weld-time meter for measuring duration of welding current aids control of (1) electrode contour, (2) current delivered to weld, (3) electrode pressure and (4) duration of welding current. It is used to check schedule set by welding control. Unit is portable, direct reading (in seconds and cycles), has calibrating device built-in so that it does not need separate source of supply, and is insensitive to heat control.—*Westinghouse Electric Corp., P. O. Box 868, Pittsburgh, Pa.*

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130-kv. X-ray Tube

New high-voltage tube reduces exposure of patient to x-ray by as much as 87 percent; provides one answer to geneticists' warning that radiation exposures be reduced in order to avoid any possibility of affecting human hereditary factors. Geneticists warn particularly about exposure of body areas in which reproductive organs are located; it is precisely in these areas that benefits of using new higher-voltage tube are most pronounced. Reduction of 87 percent applies to a typical exposure for radiography of the pelvis, or of other thick sections of human body. Conventional tubes are generally designed to operate at voltages between 30,000 and 80,000. New tube, designed for operation at 130,000 volts, is incorporated into makers' "robot" x-ray machine ("Maxiscope 500"), permits showing a wider variation of thicknesses on a single x-ray film and to get finer detail on films taken of thick sections of body. Announcement states that, until recently, loss of definition in

films taken above 110,000 volts prevented adoption of high-voltage technique; and that design of new tube eliminated this problem. New tube should find applications also in medical research, as in development of cinefluorography, or in x-raying of tissue specimens in pathology—*General Electric X-Ray Corp.*, 4855 *West McGeoch Ave., Milwaukee* 14, *Wis.*

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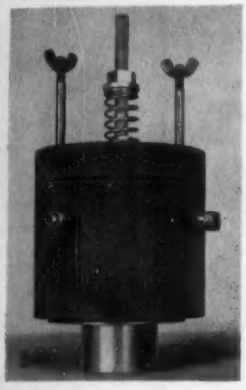
Tension and Compression Pick-ups

New "Tate Emery Air Cells" having load ranges of 0-1.2 to 0-6 lb. and 0-2 to 0-10 lb. in tension and compression were designed for use on testing machines to measure small loads such as in testing plastics, paper, etc.; can also



be used independently for such purposes as weighing chemicals, or controlling chemical processes. When "Tate-Emery" indicator with 66-in. scale is connected with cell, 0-2 lb. range shows pointer movement of approx. 2 in. for one ounce or 0.0625 in. for one gram. Ranges are changed in indicator. Portable Bourdon-gage-type indicators with 22-in. scale are available with these cells when existing indicators do not readily accommodate additional ranges. Minimum range with this type indicator is 0-10 lb. Air jet and baffle within cell controls action of pneumatic force balance system, so that air pressure automatically balances load. Total movement of load-sensitive member is less than 0.0005 in. This air pressure is transmitted to load indicator. Accuracy of load measurement is within 0.75 percent of reading or 0.15 percent of capacity, whichever is greater, when Bourdon-gage-type indicators are used. —*Baldwin Locomotive Works, Philadelphia* 42, *Pa.*

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New radium-beryllium neutron sources with marked improvement in neutron-to-gamma emission ratio, and permitting duplication of results, can be provided in a powdered radium-beryllium mixture or a compressed radium-beryllium mixture, in any size, from a few mg. content for college laboratory routine experimentation, to 1,000 or more mg. for special applications. Packaged in stainless steel or

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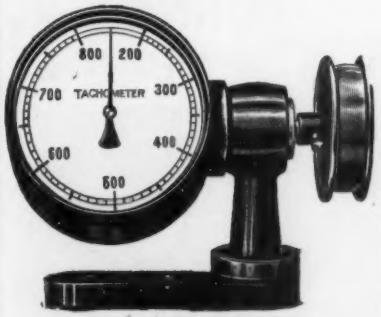

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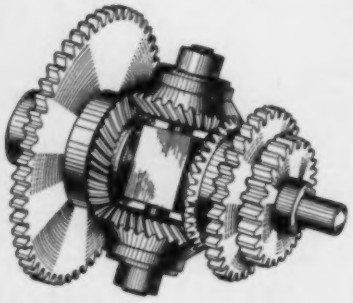

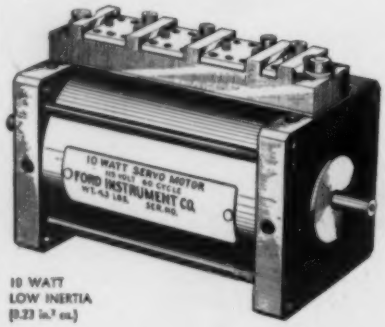

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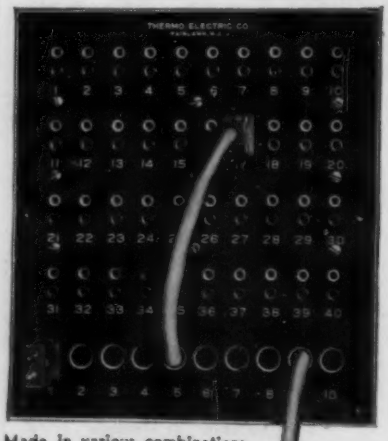

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New "Type 3OHL1 Electronic Timer" provides intervals from 0.05 second to four minutes, in four basic types of

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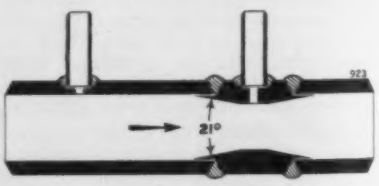
Small-size Venturi Tubes

New fabricated Venturi tube assemblies, for line sizes between 0.75 in. and 3 in., are supplied with welding



ends, with stub-end welding nipples for measurement connections. They can be furnished in steel, stainless steel, Monel, brass, bronze or any other metal which can be obtained in tubular and bar forms and which can be readily welded or brazed. New tubes are particularly useful: (1) where line fluid velocities are so high that excessive differential range is required with an orifice plate; (2) where solids in suspension in line fluid tend to deposit on or near orifice plate.—*Republic Flow Meters Co., 2240 Diversey Pkwy., Chicago 47, Illinois.*

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Kilovoltmeter

New "Model 4000" kilovoltmeter measures television and x-ray voltages up to 50,000 volts d.c. It is a 20-microampere

instrument with an input impedance of 1250 megohms. Basic sensitivity of instrument is 50,000 ohms per volt. All voltage is dissipated in shielded polystyrene probe; test leads are shielded, and shields are connected together for greater safety; "normal-reverse" key is provided so that probe may be used regardless of polarity of voltage under test. Indicator has large clear scale so that measurements as low as 3000 volts can be read. — *Bradshaw Instruments Co., 348 Livingston St., Brooklyn 17, N. Y.*

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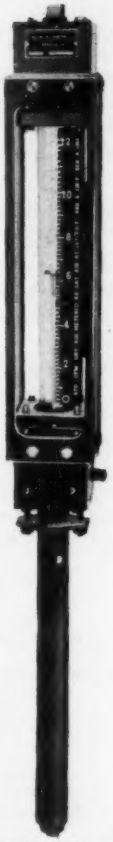

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Engineers often tell us that they use the rotameter only as a flow guide. However, what good is the guide if it is 5% to 25% *inaccurate*. It is like a street sign prankishly turned 90° the morning after Hallowe'en—it leads in the wrong direction.

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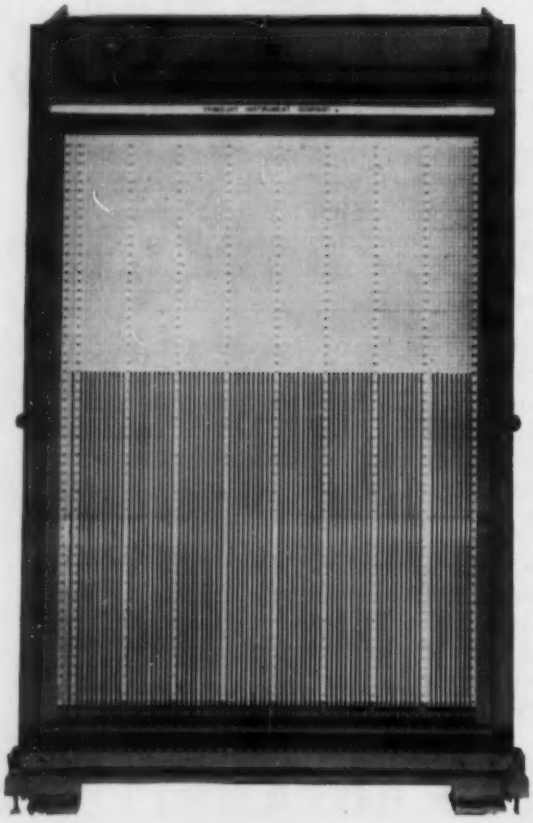

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TEMPERATURE CONTROL *Continued from page 224*

This formula will allow us to calculate t_2 by successive approximations, as we find t_2 both in the left hand and in the right hand members of this formula.

We shall determine now the value Q_3 of the heat input per unit of time at the moment when the temperature inside the heating unit reaches again its original value θ_1. If we introduce in formula (28) the corresponding values of Q, t, and θ which are Q_3, t_2 and θ_1 we have:

$$Q_3 = Q_1 + K_1(t_1 + t_2) \qquad \ldots(34)$$

or, if we replace (t_1+t_2) by its value given by formula (32)

$$Q_3 = Q_1 + vQ_1 + \left[\frac{mK_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\times \left\{1-\exp\left\{-\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{m(\theta_1-\theta_0)}\right]t_2\right\}\right\}$$

We have previously seen, on the other hand, that the altered value of the heated fluid flow, after the disturbance has taken place, is equal to:

$$q_2 = (v+1)q_1 = \frac{(v+1)Q_1}{\theta_1-\theta_0}$$

from whence: $(v+1)Q_1 = q_2(\theta_1-\theta_0)$

We can therefore write:

$$Q_3 = q_2(\theta_1-\theta_0) + \left[\frac{mK_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\times \left\{1-\exp\left\{-\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{m(\theta_1-\theta_0)}\right]t_2\right\}\right\}$$

In this way, a balance at the temperature θ_1 between the heat input Q_3 and the heat output $q_2(\theta_1-\theta_0)$ carried away by the heated fluid is only possible if the second term of the right-hand member equals 0 which, in turn, is only possible if $t_2=0$. On the other hand, t_2 being the time required for a change-over from the temperature θ_3 to the temperature θ_1, t_2 cannot equal 0, unless $\theta_3=\theta_1$, i.e., unless there is no variation of temperature inside the heating unit and, consequently, no disturbance in the flow of the heated fluid drawn off from the latter.

Therefore, as long as there is any variation of the flow of heated fluid—which is the only case of interest to us—the second term of the right-hand member of the preceding relation will never equal 0 and there will never be any balance at the temperature θ_1; we will thus always have: $Q_3 > q_2(\theta_1-\theta_0)$ and the temperature inside the heating unit will overshoot and will be stabilized at a given temperature $\theta_4 > \theta_1$.

We shall now study the continuation of the increasing branch of the curve $\theta(t)$ beyond the original temperature θ_1 between θ_1 and θ_4. We shall assume to begin with, that the temperature of balance θ_4 is lower than the limit temperature θ_5 at which the controller action is started again but in a direction opposite to that of its original action.

Under these conditions—which correspond to the assumption that the temperature inside the heating unit will be stabilized between the limit temperatures θ_1 and θ_5 at which the automatic temperature controller action starts—the portion of the increasing branch of the curve $\theta(t)$ between the temperatures θ_1 and θ_5 will correspond to a variation of temperature without any influence of this controller and the heat input to the heating unit per unit of time will remain constantly equal to Q_3; we can therefore, write for this portion of the curve $\theta(t)$:

$$Q = Q_3 = Q_1 + K_1(t_1+t_2)$$

If we compare this relation with the general expression:

$$Q = Q_1 + f(\theta,t)$$

we shall find: $f(\theta,t) = K_1(t_1+t_2)$

If we replace $f(\theta,t)$ by its above value in general equation (1) we shall find that the latter becomes, for the portion of the increasing branch of the curve $\theta(t)$, between temperatures θ_1 and θ_4:

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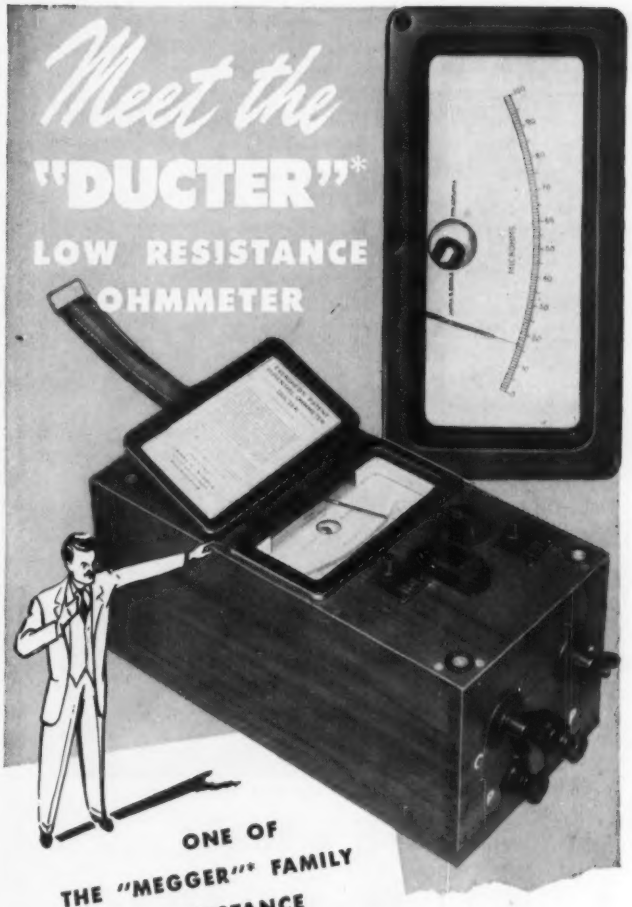

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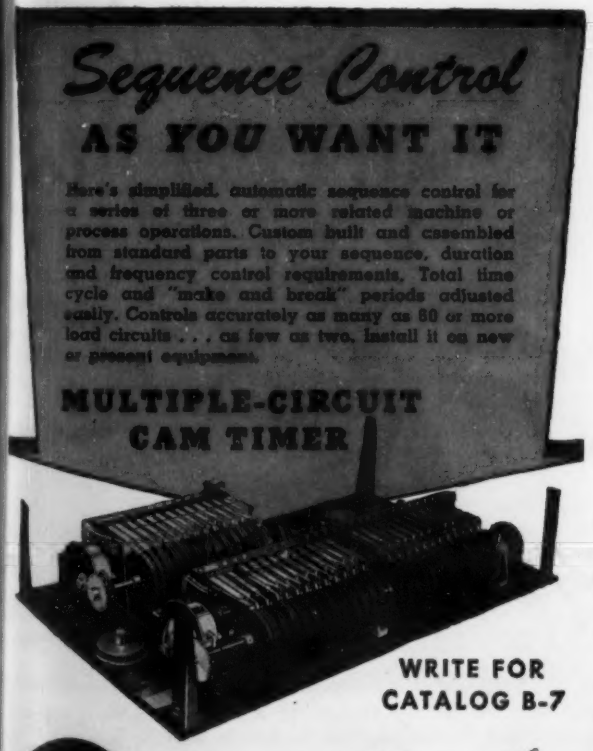

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$$-m\frac{d\theta}{dt}=\left[\frac{\theta-\theta_0}{\theta_1-\theta_0}(v+1)-1\right]Q_1-K_1(t_1+t_2)$$

or: $$-m\frac{d\theta}{dt}=\frac{(v+1)Q_1}{\theta_1-\theta_0}(\theta-\theta_1)+vQ_1-K_1(t_1+t_2) \qquad \ldots(35)$$

If we make $\theta=\theta_1$ in equation (35) we obtain:

$$d\theta/dt=-vQ_1/m+K_1(t_1+t_2)/m$$

This is the expression of the slope of the curve $\theta(t)$ at the point at which it reaches again the original temperature θ_1, i.e., at the moment $t=t_1+t_2$; if we compare it with the expression of the slope of the same curve at the point at which it leaves the original temperature θ_1 and decreases down to θ_2, i.e., at the moment $t=0$, we notice that this last slope equals $-vQ_1/m$ and, therefore, is different from that at the point $t=t_1+t_2$, this difference corresponding to the term $K_1(t_1+t_2)/m$. We will use later on this property of both angular coefficients of the curve $\theta(t)$ at the points $t=0$ and $t=t_1+t_2$ in order to determine graphically the coefficient K_1.

We shall determine now the temperature of balance θ_4 by substituting $d\theta/dt=0$ in equation (35). We have then:

$$\theta_4=\theta_1+\left[\frac{\theta_1-\theta_0}{(v+1)Q_1}\right]\left[K_1(t_1+t_2)-vQ_1\right] \qquad \ldots(36)$$

We shall determine now the equation of the portion of the increasing branch of the curve $\theta(t)$ between temperatures θ_1 and θ_4. It will be sufficient, in order to do so, to integrate directly the differential equation (35) between the limits θ_1 and θ on one hand and 0 and t on the other hand.

By separating the variables and by integrating between the above limits, we obtain:

$$t=-\frac{m(\theta_1-\theta_0)}{(v+1)Q_1}\log\left\{\frac{\frac{(v+1)Q_1}{\theta_1-\theta_0}(\theta-\theta_1)+vQ_1-K_1(t_1+t_2)}{vQ_1-K_1(t_1+t_2)}\right\} \qquad \ldots(37)$$

a relation which will be useful to us later on.

Formula (37) gives us, on the other hand:

$$\frac{\frac{(v+1)Q_1}{\theta_1-\theta_0}(\theta-\theta_1)+vQ_1-K_1(t_1+t_2)}{vQ_1-K_1(t_1+t_2)}=\exp\left\{-\left[\frac{(v+1)Q_1}{m(\theta_1-\theta_0)}\right]t\right\}$$

from whence:

$$\theta=\theta_1-\frac{(\theta_1-\theta_0)}{(v+1)Q_1}[vQ_1-K_1(t_1+t_2)]+\frac{(\theta_1-\theta_0)}{(v+1)Q_1}[vQ_1-K_1(t_1+t_2)]\times$$

$$\exp\left\{-\left[\frac{(v+1)O_1}{m(\theta_1-\theta_0)}\right]t\right\}\text{and}\ \theta=\theta_1+\frac{(\theta_1-\theta_0)}{(v+1)Q_1}[K_1(t_1+t_2)-vQ_1]\times$$

$$\left\{1-\exp\left\{-\left[\frac{(v+1)Q_1}{m(\theta_1-\theta_0)}\right]t\right\}\right\} \qquad \ldots(38)$$

which is the equation of the curve $\theta(t)$ between temperatures θ_1 and θ_4.

If we compare equation (38) with formula (36) we see that it is necessary to make in the former $t=\infty$ in order to obtain $\theta=\theta_4$. This means that, as could have been expected, the curve $\theta(t)$ tends to an asymptotic limit $\theta=\theta_4$.

We shall therefore determine in an approximate way (with an approximation of 1°) the time required to stabilize the temperature and will thus determine the time required by the temperature inside the heating unit to pass from θ_1 to $\theta_4''=\theta_4-1°=\theta_1+$

$$\frac{(\theta_1-\theta_0)}{(v+1)Q_1}[K_1(t_1+t_2)-vQ_1]-1$$

If we introduce this value of θ_4'' in formula (37) previously obtained it will be easy to find the approximate time t_2 required for stabilizing the temperature inside the heating unit; we have in this way:

$$t_2=\frac{m(\theta_1-\theta_0)}{(v+1)Q_1}\log\left\{\frac{(\theta_1-\theta_0)\,[K_1(t_1+t_2)-vQ_1]}{(v+1)Q_1}\right\}$$

On the other hand, formula (36) gives us the following relation between $\theta_4-\theta_1$ and $\theta_1-\theta_0$:

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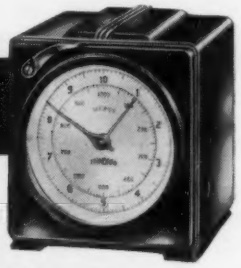

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*Vandaveer, Industrial & Engineering Chemistry, Vol. 22, page 596, June 1930.

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$$\theta_4-\theta_1=\frac{(\theta_1-\theta_0)}{(v+1)Q_1}[K_1(t_1+t_2)-vQ_1]$$

which enables us to write:

$$t_5=\frac{m(\theta_4-\theta_1)\log(\theta_4-\theta_1)}{K_1(t_1+t_2)-vQ_1} \quad \ldots(39)$$

It is interesting to compare the series of formulae which we have obtained for the portion of the increasing branch of the curve $\theta(t)$ comprised between the temperatures θ_1 and θ_4 with the corresponding formulae obtained at the beginning of this essay in the case of heating units not provided with any temperature controller; if we compare thus between them formulae (38) and (6) which give in both cases the equation of the curve $\theta(t)$ or if we compare formulae (36) and (3) which give the values of the respective temperatures of balance θ_4 and θ_2 or, at last, if we compare formulae (39) and (7) which give the respective time intervals t_2 and T required for stabilization, we will see that these formulae are identical with this difference that the term $-vQ_1$ which we find in the case of heating units not provided with temperature controllers is replaced by the term $K_1(t_1+t_2)-vQ_1$, in the case of the portion under review of the increasing branch of the curve $\theta(t)$.

This phenomenon should not surprise us, because, according to the assumption which we made before we began to study the operation of the heating unit between the temperatures θ_1 and θ_4, this operation takes place without any intervention of the automatic temperature controller—which explains the fact that the formulae obtained for the corresponding portion of the increasing branch of the curve $\theta(t)$ are similar to those determined at the beginning of this essay in the case of operation without any temperature controller—and, furthermore, because the slope of the increasing branch of the curve $\theta(t)$ equals, as we have already seen $\frac{K_1(t_1+t_2)-vQ_1}{m}$ for $\theta=\theta_1$ while the slope of the decreasing branch of the same curve equals $\frac{-vQ_1}{m}$ for the same temperature $\theta=\theta_1$ (i.e., for $t=0$) whether the case considered is that of a heating unit equipped with a temperature controller or not.

We have assumed, to begin with, that the temperature of balance θ_4 was lower than the limit temperature θ_5 at which the automatic temperature controller starts again its action, but, this time, in a direction opposite to that of its former action.

If it were otherwise, there would not be any stabilization of temperature at all, as when the temperature inside the heating unit would reach the limit θ_5, the controller would start its action and the latter would continue, as we have already seen, beyond the moment when the temperature $\theta_4'>\theta_5$ is reached, although there would be a balance at this last temperature between the heat input to the heating unit and the heat output carried away by the heated fluid.

The temperature inside the heating unit would therefore decrease again after having reached its maximum for $\theta=\theta_4'$ and this would result in a series of cycles starting with the described temperature variation which would follow the dotted line tracing in Fig. 5; this "hunting" would last until the continuation of the curve $\theta(t)$ would be again within the temperature interval limited by the temperatures θ_1 and θ_5 which correspond to a start of the controller action.

Therefore, the mathematical condition of absence of any hunting after a variation of the flow of the heated fluid can be expressed by:

$$\theta_4<\theta_5$$

or, by replacing θ_4 by its value given by formula (36):

$$\theta_1+\left[\frac{\theta_1-\theta_0}{(v+1)Q_1}\right][K_1(t_1+t_2)-vQ_1]<\theta_5$$

from whence:

$$V>\frac{K_1(t_1+t_2)(\theta_1-\theta_0)}{Q_1(\theta_5-\theta_0)}-\frac{(\theta_5-\theta_1)}{(\theta_5-\theta_0)}$$

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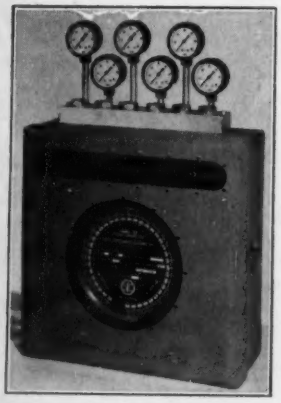

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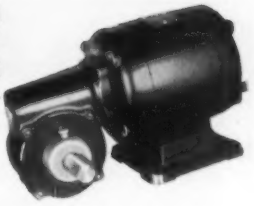

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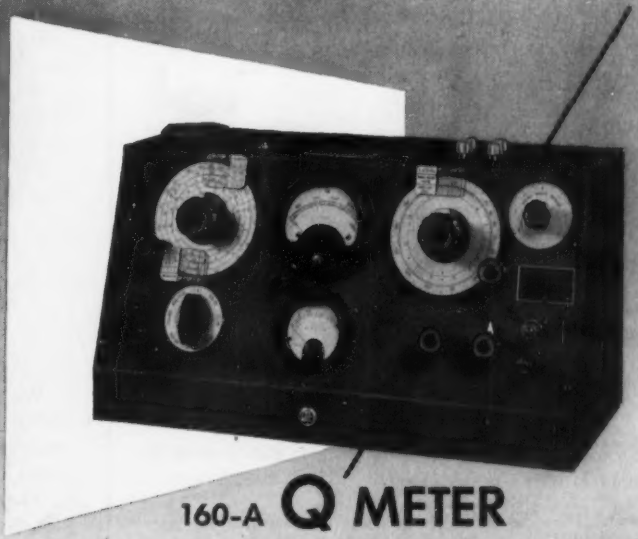

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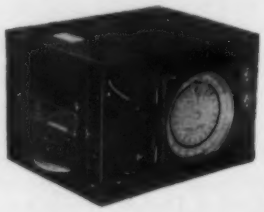

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control—for all the values of the relative variation of the heated fluid flow greater than a minimum equal to:

$$V_{min}=\frac{K_1(t_1+t_2)(\theta_1-\theta_0)}{Q_1(\theta_5-\theta_0)}-\frac{(\theta_5-\theta_1)}{(\theta_5-\theta_0)}$$

On the other hand, if we examine formula (32), we see that:

$$t_1+t_2>vQ_1/K_1 \text{ unless } t_2=0 \text{ and, therefore, } v=0$$

This relation gives us:

$$V<\frac{K_1(t_1+t_2)}{Q_1}$$

The relative variations of the heated fluid flow are therefore always smaller than a maximum equal to:

$$V_{max}=\frac{K_1(t_1+t_2)}{Q_1}$$

We can therefore say that the condition of stability of control which we have mentioned above, corresponds to relative variations of the heated fluid flow comprised between the two limit values V_{max} and V_{min} which we have just determined.

The interval between these limit values—which we will call "interval of stability"—is obviously peculiar to the stability of the considered automatic temperature control.

This interval of stability is, therefore, equal to:

$$S=V_{max}-V_{min}$$

or, by replacing V_{max} and V_{min} by their previously determined values:

$$S=\left[\frac{K_1(t_1+t_2)}{Q_1}\right]\frac{(\theta_5-\theta_1)}{(\theta_5-\theta_0)}+\frac{(\theta_5-\theta_1)}{(\theta_5-\theta_0)}$$

If we call, on the other hand: $s=\dfrac{\theta_5-\theta_0}{\theta_5-\theta_1}$

the relative sensitivity of the considered automatic temperature controller, we will have:

$$S=\frac{K_1(t_1+t_2)+Q_1}{sQ_1} \qquad \ldots(40)$$

We can see that, when $\theta_5=\theta_1$, $s=\infty$ and the sensitivity of the controller becomes infinite, while $S=0$ and its stability decreases down to 0. It is therefore useful, from the standpoint of stability of control, to have controllers as insensitive as possible, this conclusion being similar to that which we have made for the discontinuous automatic control.

On the other hand, if we replace in formula (40) the term $K_1(t_1+t_2)$ by its value given by formula (32), we will have:

$$S=\frac{v+1}{s}+\frac{\left[\dfrac{mK_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]\times}{sQ_1}$$

$$\left\{1-\exp\left\{-\left[\frac{(v+1)Q_1+K_2(\theta_1-\theta_0)}{m(\theta_1-\theta_0)}\right]t_2\right\}\right\}$$

We can therefore conclude that for a given value s of the sensitivity of the considered automatic temperature controller, the stability of control S increases with the increase of the fictitious mass m of the heating unit.

The influence of the coefficient K_2 on the temperature interval $\theta_1-\theta_2$ is greater than that of the coefficient K_1 as K_2 appears in the first degree in the second right-hand term of formula (26) and in a quadratic form in the third term of this formula, while K_1 is not contained at all in the second term and is contained in the third term only in the first degree.

Therefore, it is mainly the more or less high value of the coefficient K_2 which bounds the variations of temperature inside the heating unit before the controller action has time to effect a change and to stabilize this temperature prior to restoring it back to its original value.

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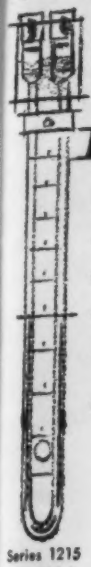

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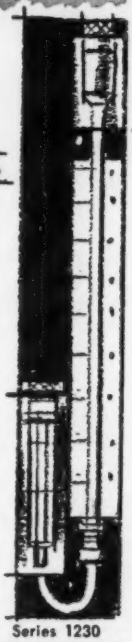

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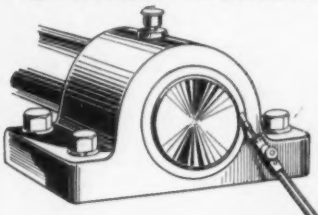

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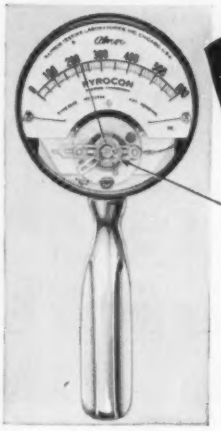

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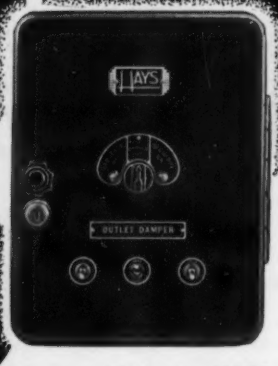

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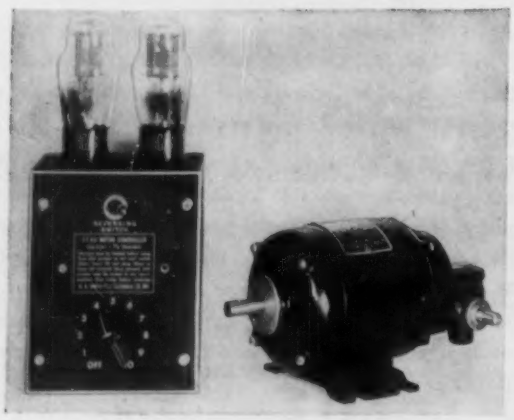

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ture of balance θ_4) in the general case of throttling automatic control with automatic reset; in the particular instance of floating automatic control, it will be sufficient to make in all the formulae which we have obtained $K_2=0$.

We shall study now the way of measuring the coefficients K_1 and K_2.

First we note that the slope of the decreasing portion of the curve in Fig. 5 is $-vQ_1/m$, while the slope of the increasing portion is

$$[K_1(t_1+t_2)-vQ_1]/m$$

at the points where $\theta=\theta_1$. We have, then, that $\tan\alpha=vQ_1/m$ and $\tan\beta=[K_1(t_1+t_2)-vQ_1]/m$. Also we find that

$$\overline{AB}=\frac{\theta_1-\theta_3}{\tan\alpha} \text{ and } \overline{CD}=\frac{\theta_1-\theta_3}{\tan\beta}.$$

On combining the above expressions we have:

$$K_1=m(\theta_1-\theta_3)\frac{\overline{AB}+\overline{CD}}{\overline{AB}\cdot\overline{CD}\cdot\overline{AD}} \qquad \ldots(41)$$

This formula will make possible the determination of coefficient K_1 from the results of an investigation of a chart corresponding to a heating unit, the fictitious mass of which has been previously measured by the methods which we have already studied.

The values of AB, CD and AD which correspond to time intervals are to be expressed in seconds; under these conditions, the coefficient K_1 is expressed in calories per second squared. With controllers which can operate either with or without automatic reset, the coefficient K_1 can be also determined from the results of two comparative tests effected: the first, with automatic reset (i.e., under throttling control with automatic reset); the second, without automatic reset (i.e., under simple positioning control), therefore with $K_1=0$.

In the first case, the temperature of first balance equals, according to formula (22):

$$\theta_3=\theta_1-\left[\frac{(\theta_1-\theta_0)(vQ_1-K_1t_1)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}\right]$$

from whence $\theta_1-\theta_3=\dfrac{(\theta_1-\theta_0)(vQ_1-K_1t_1)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}$

In the second case, i.e., when $K_1=0$, this temperature of first balance equals (see formula (26a):

$$\theta_3'=\theta_1-\frac{vQ_1(\theta_1-\theta_0)}{(v+1)Q_1+K_2(\theta_1-\theta_0)}$$

from whence: $\theta_1-\theta_3'=\dfrac{(\theta_1-\theta_0)vQ_1}{(v+1)Q_1+K_2(\theta_1-\theta_0)}$

If we divide, member by member, the two preceding relations we shall obtain:

$$\frac{\theta_1-\theta_2}{\theta_1-\theta_3'}=\frac{vQ_1-K_1t_1}{vQ_1}$$

from whence:

$$K_1=\frac{(\theta_3-\theta_3')}{(\theta_1-\theta_3')}\quad\frac{vQ_1}{t_1}\quad\frac{cal}{sec^2} \qquad \ldots(42)$$

Formula (42) allows us to determine the coefficient K_1 by maintaining during both comparative tests which we have mentioned the same values of θ_1, Q_1 and v and by observing, during the first of these tests, the values of θ_3 and of t_1 and, during the second test, the value of θ_3'; this method is obviously a less general one than that of formula (41) as it applies only to throttling automatic controllers with automatic reset, whilst formula (41) applies as well to floating controllers.

A similar method permits the determination of coefficient K_2 from the results of two comparative tests effected: the first, with the automatic controller in operation but without automatic reset (i.e., under positioning control) and, therefore with $K_1=0$, the second, with the automatic controller out of operation, i.e., simultaneously with $K_1=0$ and $K_2=0$.

If we run over the preceding formulae, the temperatures of

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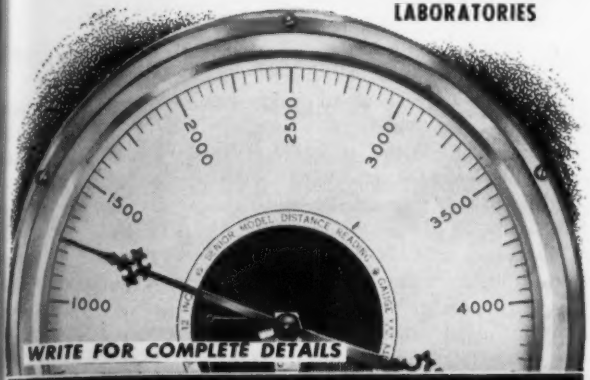

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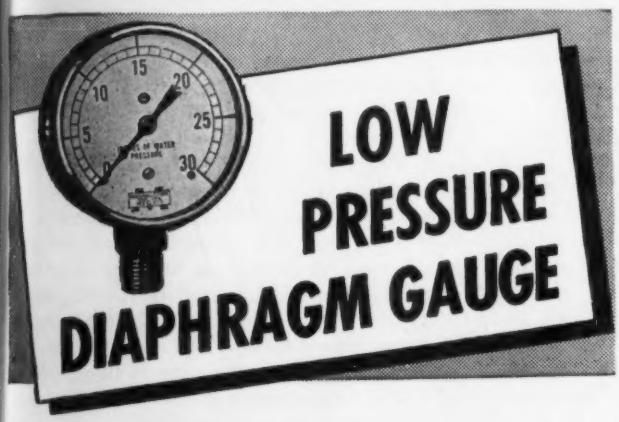

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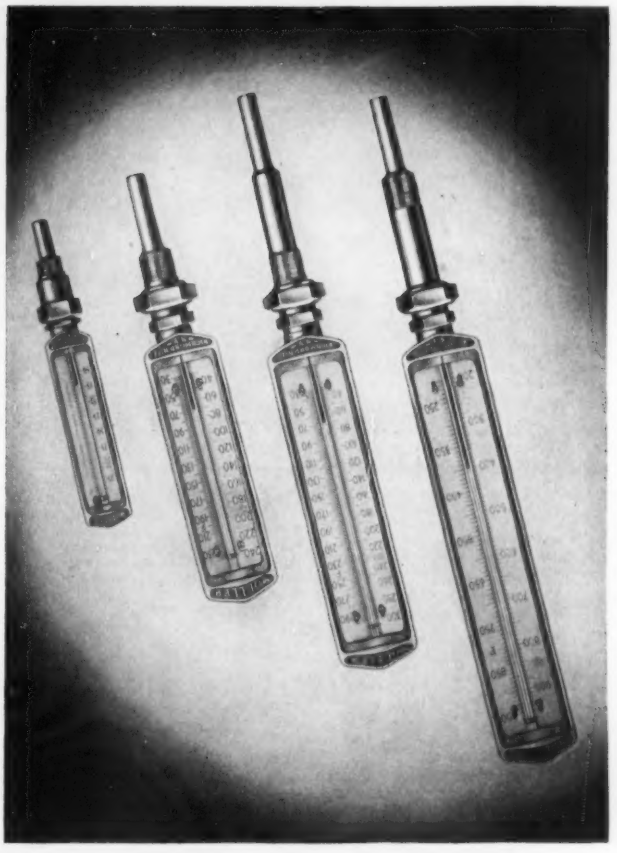

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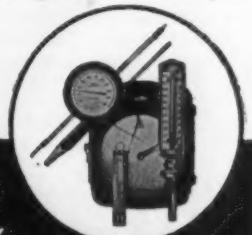

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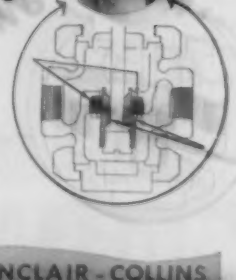

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Vol. 4 | MARCH 1949 | No. 3

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Our congratulations and best wishes go forth to this newest Section of our rapidly growing Society.

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Work is proceeding on practices for Flowmeter Installation, Flow Plan Symbols, Outside Instrument Protective Cabinets, and others.

New York Conference Again a Success

The Second Annual Regional Conference, sponsored by the New York Section, was held on Jan. 28th and 29th at the Hotel Statler in New York City. Total registration was about 250, with 75 attending the banquet on Friday evening, Jan. 28th.

On Friday morning, registration began at 8:45 A. M. and the first Technical session opened at 9:30 A. M. with W. G. Brombacher, National Bureau of Standards, as chairman. Mr. Brombacher spoke on "Some Problems in the Precise Measurement of Pressure." He was followed by W. Barton Eddison, Consulting Engineer on "New Developments in Pressure Sensitive Diaphragms" and Clifford N. Sugden, Chief Engineer, Manning-Maxwell & Moore, Inc., on "Bourdon Tube Theories."

The Friday afternoon session was led by J. B. McMahon, Republic Flow Meters Co. and Vice-President ISA. Mr. McMahon spoke on "Applications of Pressure Devices in Science and Industry" to set the tone for the session. Four papers were presented as follows:

"Basic Use of Pressure in the Process Field," C. B. Moore, Pres., Moore Products Corp., Philadelphia, Pa.

"The Precision and Accuracy of Vacuum Measurements," B. B. Dayton, Mgr., Development Group, Vacuum Equipment Div., Distillation Products, Inc., Rochester, N. Y.

"Measuring Rapidly Changing Pressures and Some Applications in Industry," David Elam, Ch. Engr., Electro-Products Laboratories, Chicago, Ill.

"Measurement of High Pressures," Prof. P. W. Bridgman, Harvard University, Cambridge, Mass.

ISA President, Carl F. Kayan presided at the Banquet on Friday evening. The gathering was favored by two features: the first was a short talk by E. S. Lee, President, American Institute of Electrical Engineers on the subject "Is Measuring a Science?"; the second talk was on the subject "Problems in Deep Sea Oceanographic Exploration" by Dr. Columbus O'D.

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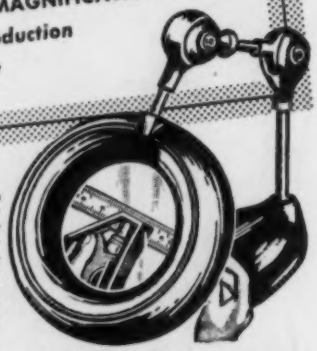

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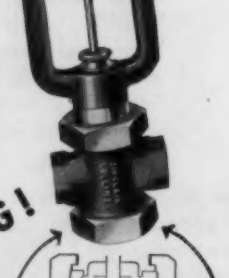

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Work is proceeding on practices for Flowmeter Installation, Flow Plan Symbols, Outside Instrument Protective Cabinets, and others.

New York Conference Again a Success

The Second Annual Regional Conference, sponsored by the New York Section, was held on Jan. 28th and 29th at the Hotel Statler in New York City. Total registration was about 250, with 75 attending the banquet on Friday evening, Jan. 28th.

On Friday morning, registration began at 8:45 A. M. and the first Technical session opened at 9:30 A. M. with W. G. Brombacher, National Bureau of Standards, as chairman. Mr. Brombacher spoke on "Some Problems in the Precise Measurement of Pressure." He was followed by W. Barton Eddison, Consulting Engineer on "New Developments in Pressure Sensitive Diaphragms" and Clifford N. Sugden, Chief Engineer, Manning-Maxwell & Moore, Inc., on "Bourdon Tube Theories."

The Friday afternoon session was led by J. B. McMahon, Republic Flow Meters Co. and Vice-President ISA. Mr. McMahon spoke on "Applications of Pressure Devices in Science and Industry" to set the tone for the session. Four papers were presented as follows:

"Basic Use of Pressure in the Process Field," C. B. Moore, Pres., Moore Products Corp., Philadelphia, Pa.

"The Precision and Accuracy of Vacuum Measurements," B. B. Dayton, Mgr., Development Group, Vacuum Equipment Div., Distillation Products, Inc., Rochester, N. Y.

"Measuring Rapidly Changing Pressures and Some Applications in Industry," David Elam, Ch. Engr., Electro-Products Laboratories, Chicago, Ill.

"Measurement of High Pressures," Prof. P. W. Bridgman, Harvard University, Cambridge, Mass.

ISA President, Carl F. Kayan presided at the Banquet on Friday evening. The gathering was favored by two features; the first was a short talk by E. S. Lee, President, American Institute of Electrical Engineers on the subject "Is Measuring a Science?"; the second talk was on the subject "Problems in Deep Sea Oceanographic Exploration" by Dr. Columbus O'D.

New York Section Regional Meeting Banquet Group

At the head table are (left to right): A. K. Joecks, Consolidated Edison Co. (New York Section); E. J. Grace, Sun Oil Co. (Chairman ISA Meetings Committee); J. B. MacMahon, Republic Flow Meters Co. (ISA Vice-President); E. S. Lee, General Electric Co. (President, American Institute of Electrical Engineers); Dr. C. O'D. Iselin, Woods Hole Oceanographic Institute; C. F. Kayan, Columbia University (President, ISA); R. R. Batcher, Consultant (President, New York Section, Chairman ISA Publications Committee); N. J. Cherry, The Bristol Co. (Treasurer, N. Y. Section); W. G. Brombacher, National Bureau of Standards; C. O. Fairchild, Consultant (Past-President, ISA).

Iselin, Director, Woods Hole Oceanographic Institute, Woods Hole, Mass.

As always the remarks of E. S. Lee were very interesting and thought provoking. He stressed the importance of instruments and instrument men in production control, quality control, and many other fields. The burden of his talk was "tell the instrument story and keep on telling it, because until we can measure a thing and express the measurement in numbers, we cannot say that we know much about it."

Dr. Iselin described problems of particular interest to instrument people and expressed a few desires for some equipment that is not in existence. He had the power, and used it, to stir the imagination of all those present with his descriptions of current studies, depth measurements and conditions under which instruments must work in deep sea exploration.

The Saturday sessions, under the chairmanship of A. K. Joecks, Ass't Test Engr., Consolidated Edison Co. of N. Y. were designed primarily for instrument service engineers and technicians. Starting with "Fundamentals of Pressure Measurements" by Prof. E. P. Lambe, Pratt Institute, the following subjects were covered:

"Checking Static and Differential Pressure Instrument in the Plant," Messrs. C. J. Zeller, W. Crosson, E. M. Carney and R. Hutcheon, Consolidated Edison Co. of New York.

"Field Servicing of Pressure Instruments," Energy Control Co., New York.

"Operation of an Instrument Repair Shop," Manning, Maxwell & Moore, Inc.

"Pressure Gauges," Crosby Steam Gage & Valve Co., Boston.

"Pressure Bellows," Barton Instrument Co., Los Angeles.

"Draft Gauges," Energy Control Co., New York.

"Venturi Meters," Builders Iron Foundry, Providence, R. I.

"Recording Pressure Gauges," The Bristol Co., Waterbury, Conn.

"Flow Meters," Republic Flow Meter Co., Chicago.

"Ring-Balance Flow Meter," Hagan Corp., Pittsburgh.

This Conference, like the first one in January 1948, was a success and the New York Section is planning a third conference for January 1950. No subject has been selected and suggestions may be sent by any interested member to the Secretary of the Section (See Table).

Section News

AKRON

Continuously increasing interest in instrumentation was evidenced at the February meeting of the Akron Section, when 75 members and guests were present at the Akron YWCA.

We were honored by the presence of Dick Rimbach, who did a grand job of plugging for the coming St. Louis show, particularly for the pre-convention intensive training course; and of M. S. Jacobs, our regional member of the Sections Committee, who described the necessity for each Section's keeping in mind the needs of the ISA for officers, committee members, etc., and of recommending those of its members who are able and capable.

The business portion of the meeting was concerned primarily with the consideration of the Section Constitution and By-Laws, which were then adopted by unanimous vote.

The speaker for the technical part of the program was Mr. U. C. Upton, Manager of the Electrical Instrument Dept. of the Brown Instrument Division. Mr. Upton worked out on an Electronik temperature recorder which he had previously manhandled to the point where it would not function at all. He demonstrated, step by step, the method of locating each trouble and of clearing it, including, we suspect, a few that were inserted by Mr. McCullough, Brown representative in Cleveland, when Mr. Upton wasn't looking. Following Mr. Upton's excellent demonstration, he called for questions, a number of which were forthcoming from all directions. In answering these, he went further into the subject of maintenance in general, using as his theme, "Know that a trouble exists, analyze it, locate it, know the right set-up, make it right."

Delegate C. B. Luther reported on the New York Section Conference, which he attended.

Following a spirited discussion on the operation, merits and demerits of the Section Employment Committee, the meeting was adjourned. —FRED APPEL, JR., Se'cy.

BOSTON

The fourth meeting of the season was held at Patten's Restaurant in Boston. Although a heavy snow storm made traveling conditions bad, sixty-two members were present at the dinner.

Mr. E. R. Hoffman, president of the Section, introduced the after-dinner speaker, Mr. J. A. Pellettere, Chief Instrument Engineer, Gulf Oil Corp., who spoke on "Interconnected Control Instrumentation for Systems involving Unfavorable Lags." Mr. Pellettere's address was well received and the members showed their interest by asking the speaker many questions.

The next meeting of the Boston Section will be held on February 23, 1949, at the Boston Yacht Club, Rowe's Wharf, Atlantic Avenue. Mr. W. N. Greer of the Leeds & Northrup Co. will address the meeting, his subject being: "Measurement of pH and Conductivity." —J. H. CONDON, Corr.

CENTRAL INDIANA

The annual instrument show, sponsored by the Central Indiana Section was held Feb. 1st, at the Athenaeum. Many new products in the field of instrumentation and control were exhibited. The companies participating in the event were: Acme Engineering Co., Bristol Co., Brown Instrument Div., Brush Development Corp., Consolidated Equipment Co., I. W. Cotton Co., Esterline-Angus Co., C. S. Gordon Co., Meters, Inc., Minneapolis-Honeywell Regulator Co., National Engineering Co., Republic Flow Meters Co., Rockwell Engineering Co., Struthers Dunn, Inc., Taylor Instrument Co's., and the Wheelco Instruments Co.

The March 8th meeting will be held at the Purdue Extension Center. Mr. W. Ellsworth of the C. S. Gordon Co. will talk on "Measuring and Controlling Temperature." —E. E. TAYLOR, Corr.

CHARLESTON

The February meeting of the Charleston Section was held on Feb. 7th at 8:00 P.M. Dinner for fifteen was served at 6:30 P.M. at the Army and Navy Club. Mr. Thomas J. Kirwin, the newly elected president of the Charleston Section, presided over the meeting. The minutes of the previous meeting were read by Mr. A. Hix, secretary.

The guest speaker for the evening was Mr. T. B. Burris, Sales Manager, Petro-Chemical Div., Fisher Governor Co., Marshalltown, Iowa, who gave a very informative talk on the subject "Control Valves and High Pressure Regulators." His talk

(*Continued on Page 273*)

SEE ARTICLE ON NEXT PAGE

THE AUTHORS

D. P. Eckman

R. B. Werey

D. P. Eckman received his BSE Mechanical Engineering in 1938 and MS in 1939 from the University of Michigan. From 1939 to 1946 he was engaged in research for Brown Instrument Division, Minneapolis-Honeywell Regulator Company. At present he is Consultant to Conoflow Corp. and Instructor, Sibley School of Mechanical Engineering, Cornell University.

R. B. Werey graduated in Chemical Engineering from the University of Michigan in 1921. His first ten years' experience was obtained in the petroleum refining industry in Texas, Oklahoma and New York. He left M. W. Kellogg Co. in 1930 to enter the industrial instrument and control field. For seven years prior to the formation of Conoflow Corp. in 1943, he was Assistant Sales Manager, Petroleum and Chemical Industry for Brown Instrument Division.

Control Valve Body Design

By DONALD P. ECKMAN* and R. B. WEREY**

IN ANY review of the progress made in the use of industrial automatic control systems, major emphasis is usually placed on the developments which have taken place in the indicating, recording and controlling instrument. This is as it should be since, after all, it is the measuring and controlling means which constitute the main operating center of a controller, and without them it would be impossible to accomplish any sort of satisfactory automatic control.

However, a controlling instrument does not constitute the entire control system. The controlling instrument must be implemented with a final control element. This final control element can take many forms, but it is generally a fluid regulating device such as a valve, damper or louver positioned by an electric, pneumatic or hydraulic power motor.

This article is concerned with the subject of control valves as they are used in the field of industrial automatic control. In the main the discussion is limited to the flow of liquids and the valve is considered to be a throttling type. We wish to inquire into some of the more fundamental aspects of valve body design and to point out the need for additional research and development in this field. A number of questions will be raised dealing with improvements in control valve body design; not all of them will be answered.

First, we should outline the requirements for any ideal automatic control valve. These are, among others:

1. It should be simple for easy maintenance.
2. It should have a smooth and consistent calibration of lift versus flow at all pressure differentials.
3. It should have reasonable flow capacity at an economical size.

In addition, an automatic control valve must be able to handle a wide variety of liquids, gases and vapors and meet other such application requirements. These latter will not be discussed.

Control Valves vs. Conventional Valves

Conventional gate and globe valves are not in general use for automatic control, as every user knows, and it is necessary to design valve bodies and valve operators specifically for control service. Valve operators and valve bodies are rarely considered as items obtained separately and assembled on the job; expediency and effective operation make it desirable to obtain the combination as a single integrated unit.

*Consultant, Conoflow Corp., Sibley School of Mechanical Engineering, Cornell University.

**Conoflow Corporation.

In their simplest form, control valves differ from the conventional gate and globe valves in three ways:

1. Control valves are positioned from an external source of power while hand valves are, in general, positioned by hand wheel and screw stem.
2. Control valves have restricted port openings and operate under throttling conditions with attendant high velocities across the orifice. Gate and globe valves have full port openings to pass a maximum flow with a minimum of pressure loss.
3. Present-day control valves usually have a balanced inner valve whereas hand valves have single seated unbalanced inner valves.

The first point is a consequence of the requirement for operating control valves remotely. A power motor of some sort is required for moving and positioning the inner valve in accordance with the dictates of a controlling instrument.

The second point has to do with fundamental differences in body design. A control valve is a variable orifice and always operates under either fixed or variable pressure differentials. The ideal control valve should have a minimum of velocity head loss in body passages. All energy losses should be confined to the valve port proper. A variable throat Venturi would make an ideal control valve were it physically possible to construct such a device. The nearest practical approach to a variable throat Venturi is undoubtedly a single seated valve with streamlined plug and with body contours such that there is a minimum of change in direction of flow through the valve passages and a minimum mixing and rotation of the flow stream.

The third point has to do with power requirements. A double-ported valve requires a minimum of external power to operate it almost regardless of internal pressure differentials. Single seated valves require considerable power for good operation because maximum unbalanced forces are directly proportional to the area of the valve seat and the pressure differential across the seat. Were it not for this important difference, it is quite evident that conventional single seated globe valve bodies might well be adapted to control service. It is understood, of course, that modifications would be required in the plug and seat design for such services.

The rate of absorbing energy at the valve is equal to

$$(1) \quad E_A = Q\,(P_2 - P_1)$$

where E_A = energy absorbed per second
Q = flow cu. ft. per sec.
(P_2-P_1) = pressure dierential lbs. per sq. ft.

For any given flow, the energy absorbed is directly proportional to the pressure differential. The minimum absorbed energy can never be zero because we can never construct a valve which passes a given flow at zero pressure differential.

Origin of Balanced Control Valve

In order to clarify the reasons for the present-day use of control valves with balanced inner valves, it is necessary to review briefly the early history of automatic controller development.

One of the earliest types of automatic control mechanisms was the direct-connected float-operated liquid-level controller where the only power available for valve operation was that obtained by the buoyancy of the float. On the other hand, the liquid volumes to be controlled were often large, necessitating large valves. It is evident that the balanced inner valve provided a simple solution to the problem since it made possible the operation of control valves directly from the modest power of the float.

Later, as the technique of instrumentation improved, pilot relay mechanisms were developed by means of which the valve could be located remotely from the controlling instrument. Much of the early work in pilot relays revolved around electrical instruments; simple fractional horsepower electric motors were developed to open and close control valves.

Simultaneously with the development of the electric relay came the simple pneumatic relay. It employed a static air pressure to operate a spring and diaphragm motor mounted on the valve bonnet, but neither spring and diaphragm motors nor electric motors provide sufficient power to overcome large unbalanced forces. Consequently, it has always been necessary to use balanced valves even with pilot operated relays. From this it is evident that the principal reason for the use of double-ported balanced valve construction is that it materially reduces power requirements for positioning. However, in recent years, developments in the field of power and servo-positioning have pointed to improved and inexpensive designs of heavy duty motors which can handle large unbalanced forces and still provide extreme accuracy of positioning. Thus the primary reason for the existence of the double-ported valve is, to some extent, no longer valid.

Ideal Flow Conditions in Control Valves

A control valve can be considered as an *area* flow-meter (rotameter) for the purpose of analysis. The pressure differential across an ideal area flow-meter is constant, and the flow varies directly as to the area of opening. This simple situation is described by a form of Bernoulli's law as,

$$(2)\quad Q = KA\sqrt{\frac{2g}{\rho}(P_2 - P_1)}$$

The symbols used here are as follows,

A	= area of valve ports	ft^2
β	= area coefficient (A/E)	—
γ	= A loss exponent	
C	= ideal flow coefficient	
E	= area of valve entrance (nominal)	ft^2
e	= a loss coefficient	—
g	= acceleration due to gravity	ft/sec^2
K	= actual flow coefficient	
μ	= absolute viscosity	lbs/ft sec
N	= Reynolds number	—
P	= static pressure	lbs/ft^2
Q	= flow rate	ft^3/sec
ρ	= density	lbs/ft^3

We shall consider that the valve is installed in a pipe line as indicated in Fig. 1. The upstream and downstream pressure will be taken in the actual pipe line so that the pressure losses in the reducing sections are charged to the valve. Mainly, we are concerned with the flow of liquids since the characteristics of the fluid are not important to this discussion.

The first difficulty in applying equation (1) is that the pressure differential $(P_2 - P_1)$ is usually never constant in actual practice. However, experienced control engineers recognize the desirability of maintaining constant pressure differentials across the valve, despite the fact that such ideal conditions are often quite difficult to achieve. We shall therefore assume that the pressure differential as here defined is constant.

Variable pressure differentials at the control valve, although important, are not of vital consideration in this discussion of flow through a throttling control valve at maximum opening. This problem has been treated in detail by others (reference 3, for example). It is the theme of this report that knowledge regarding actual pressure differentials at the valve are of little use if the flow coefficient and quantity performance of the valve are not exactly known.

The second difficulty arises from the fact that fluids are not ideal; in other words, they are viscous. This results in a variation of the flow coefficient (α), not only for different valve body designs, but also for various pressure differentials and for various port openings of the valve. By analogy to the flow of fluids through either orifices or area meters we can expect the flow coefficient as here defined to be less than 1.0 since the actual flow is less than the theoretical flow. This illustrates the effect of fluid friction or viscous phenomena.

The third difficulty is that the pressure differential across the actual port opening of the conventional double-ported valve cannot be a constant because of pressure losses in the valve body and port passages. It is common practice to neglect these losses in order to be able to use a simple valve flow formula. This, however, is not valid, especially when control valves are used under high pressure differentials.

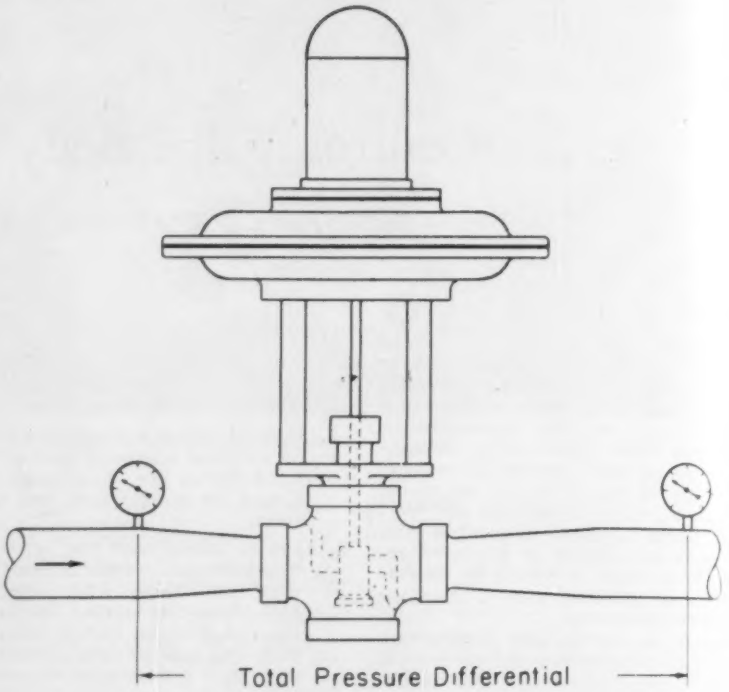

Fig. 1. Pressure differential at valve.

Pressure Losses in Control Valves

The extent of pressure losses in the passages of a valve body varies with the design of these passages; their size, shape, contour, change of direction, smoothness and so on. For the most part these losses are caused by increased turbulence and mixing of the flow stream resulting in an energy "loss" as heat.

We may illustrate the pressure losses in a conventional control valve by using a diagram such as Fig. 2. The valve entrance passage is represented by the left hand serrated section and the valve exit passage by the right hand serrated section. The area-changing-device or valve port is shown in the center. If the sections were sufficiently far apart we would be able to draw a static pressure diagram as in Fig. 3. The pressure differential across the entire valve is constant at any flow rate. For small flow rates the pressure losses in the valve entrance and exit passages are small, and almost the entire pressure differential is at the port opening. However, for large flows the pressure losses are not small, and vary greatly with various types of plugs and body contours. Since the pressure differential across the entire valve is constant, the large pressure losses at high flow automatically mean smaller pressure differentials at the port opening. Actually we know very little about the actual character of these pressure distribution curves—only the general shape can be estimated.

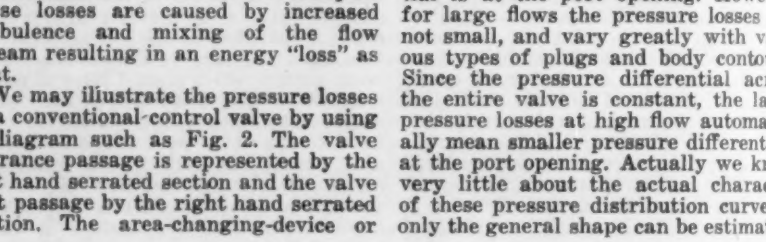

Fig. 2.

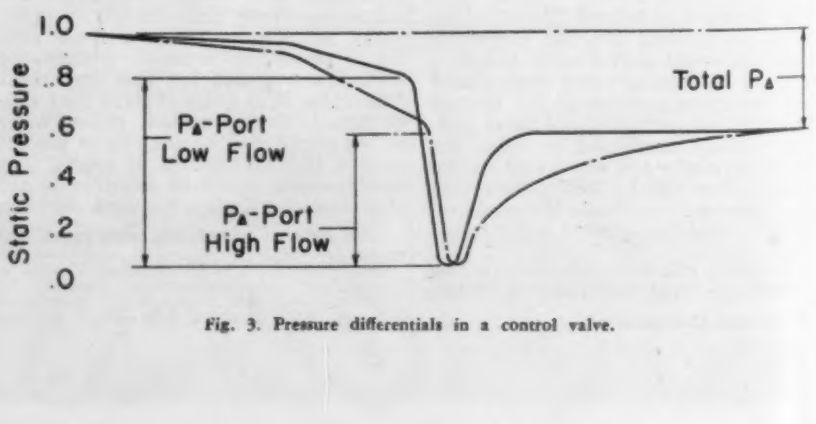

Fig. 3. Pressure differentials in a control valve.

Pressure losses in a control valve and its passages may be included in the simple formula as follows,

$$(3)\quad Q = CA\sqrt{\frac{2g}{\rho}(P_2 - P_1 - P_L)}$$

where P_L represents the static pressure losses and where an ideal flow coefficient (C) is used. This ideal flow coefficient is defined by,

$$(4)\quad C = \underset{P_2 \longrightarrow P_1}{\text{Lim. } K}$$

or the ideal flow coefficient is the actual flow coefficient when the pressure differential approaches zero — thus when pressure losses are zero.

In order to solve these equations, the form of the pressure losses must be known. Ordinarily, pressure losses are assumed to be proportional to the square of velocity of flow rate. However, this is not a valid assumption and it will be shown later that this cannot be true. We can express the head losses by using dimensional analysis (see also Pigott) as follows:

$$(5)\quad P_L = \frac{\mathcal{E}\rho}{2g}\left[\frac{\mu}{\rho}\right]^{2-\gamma}\frac{Q^\gamma}{E^{\frac{2+\gamma}{2}}}$$

where γ is any real number exponent such that the pressure losses may vary as the square, first power, square root, or any other power of the flow rate or velocity in the valve passages. We have referred the pressure losses to the valve entrance passage for convenience. We see that the pressure losses depend upon the nominal valve entrance area (E) and upon the velocity of flow.

We shall further define several convenient symbols as follows:

$$(6)\quad N = \frac{Q\rho}{A^{1/2}\mu}$$

as the Reynolds number in the valve port.

$$(7)\quad \beta^2 = \frac{A}{E}$$

as the area coefficient referred to the nominal valve entrance area.

Actual Flow Conditions

We are now in a position to consider the variation of actual flow coefficient (K) with pressure differential ($P_2 - P_1$). Combining equations 2, 5, and 7 into equation 3,

$$(8)\quad \left[\frac{K}{C}\right]^2 + \mathcal{E}\beta^{2\gamma}C^\gamma\left[\frac{2g\rho E}{\mu^2}(P_2 - P_1)\right]^{\frac{\gamma-2}{2}}\left[\frac{K}{C}\right]^\gamma = 1$$

This equation is dimensionless and represents the variation of flow coefficient (K) for various pressure differentials ($P_2 - P_1$) at the valve. The loss exponent (γ) and the loss coefficient ($\mathcal{E}$) are assumed to be constants, the magnitudes of which are, for the moment, unknown. The ideal flow coefficient (C) is assumed to be constant.

The first problem at hand is to determine the value of the loss exponent (γ). Assume that the loss exponent (γ) is 1.0. The variation of flow coefficient is then,

$$(9)\quad \left[\frac{2g\rho E}{\mu^2}\right](P_2 - P_1) = \beta^4 C^2 \mathcal{E}^2\left[\frac{\left(\frac{K}{C}\right)}{1-\left(\frac{K}{C}\right)^2}\right]^2$$

This indicates that the flow coefficient (K) increases at higher pressure differentials. Since this is contrary to our experience we reject this as impossible.

Assume that the loss exponent (γ) is 2.0. The variation of flow coefficient is,

$$(10)\quad \left[\frac{K}{C}\right]^2 + \beta^4 C^2 \mathcal{E}^2\left[\frac{K}{C}\right]^2 = 1$$

This indicates that the flow coefficient (K) is independent of pressure differential and we consider this impossible.

Assume that the loss exponent (γ) is 3.0. The variation of flow coefficient is given by,

$$(11)\quad \left[\frac{2\beta\rho E}{\mu^2}\right](P_2 - P_1) = \frac{1}{\beta^{12}C^6\mathcal{E}^2}\left[\frac{1-\left(\frac{K}{C}\right)^2}{\left(\frac{K}{C}\right)^3}\right]^2$$

This equation indicates that the flow coefficient decreases at higher pressure differentials. Likewise it can be shown that the same is true for any exponent greater than 2.0. We therefore state a theorem:

The pressure losses in certain types of V-ported globe pattern valves are directly proportional to the velocity of flow through the valve raised to a power greater than two.

There are no direct means at hand for deciding further the value of the loss exponent. Mathematical devices used in investigating the slope (first derivative) of the curves and the inflection points (second derivative):

$$\frac{d\left(\frac{K}{C}\right)}{d(P_2 - P_1)} \quad \text{and} \quad \frac{d^2\left(\frac{K}{C}\right)}{\left[d(P_2 - P_1)\right]^2}$$

indicate strongly that the loss exponent must be greater than 4.0. However, we shall demonstrate that the pressure losses in certain types of valves are probably *proportional* to the *sixth power* of flow velocity!

Flow Coefficient Tests

Tests of flow coefficient at various pressure differentials were made at the Cornell University Experimental Engineering Department. These tests were made on a one-inch control valve with a single-seat V-port plug as shown in Fig. 4, with a port area of 0.64 square inches or 81.0% of line area.

The valve was installed in a 2½ inch line with very short 1-inch nipples into flanges. The upstream pressure was measured 9 pipe diameters from the valve and the downstream pressure was measured 5 pipe diameters from the valve, both with large dial indicating gauges. The flow of water at 68 deg. F. was determined by the pressure differential[1], measured by mercury manometers, from a 2-inch or a 3-inch Venturi. The variation of Reynolds number (N) in these tests is from 108,000 to 256,000.

The data on flow coefficient tests is shown in Table I. Each data point represents the arithmetic averages of two to four flow readings. The valve was tested with both forward and reverse flow as indicated by the location of high pressure on the plug.

Notice that the flow coefficient is different for reverse flow by several percent points and that the flow coefficient decreases more than appreciably as the pressure differential increases.

Comparison of Theory and Test

The selection of the loss exponent (γ) is based on the graph of Fig. 5. The curves are plotted for pressure losses varying as the 3, 4, 6 and 8 power of velocity of flow through the valve. The data plotted here is from actual test (Table I, high pressure over the plug). The various curves were made to cross at a common point by suitably varying the loss coefficient.

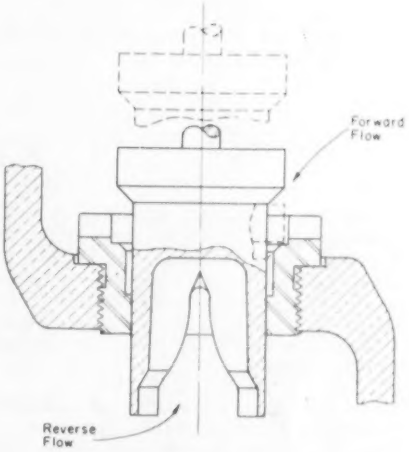

Fig. 4.

It is almost self-evident that only the curve $\gamma = 6$ comes close to matching the data; particularly if each curve were fitted to the general trend of data. It is therefore concluded that the pressure losses in certain types of inner valves are proportional to the sixth power of velocity or flow rate through the valve. The pressure losses are, therefore,

$$(12)\quad P_L = \mathcal{E}\frac{\rho^5}{2g\mu^4}\frac{Q^6}{E^4}$$

TABLE I
FLOW COEFFICIENT DATA FOR V-PORT VALVE

HIGH PRESSURE OVER PLUG		HIGH PRESSURE UNDER PLUG	
$P_2 - P_1$ PSI	FLOW COEFF. K	$P_2 - P_1$ PSI	FLOW COEFF. K
19.9	0.347	20	0.316
30.5	0.344	30	0.314
40.5	0.340	40	0.316
50.0	0.335	50	0.314
60.0	0.325	60	0.311
70.0	0.320	70	0.307
80.0	0.316	80	0.312
90.0	0.317	90	0.308
100.0	0.311	100	0.304
110.0	0.311	110	0.305
120.0	0.306	120	0.302

$$K = \frac{Q}{A\sqrt{\frac{2g(P_2 - P_1)}{\rho}}}$$

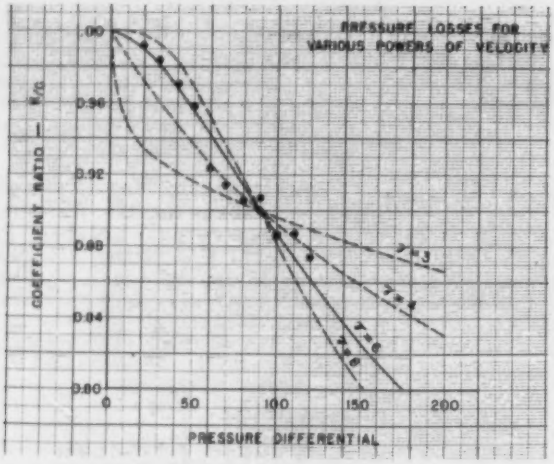

Fig. 5

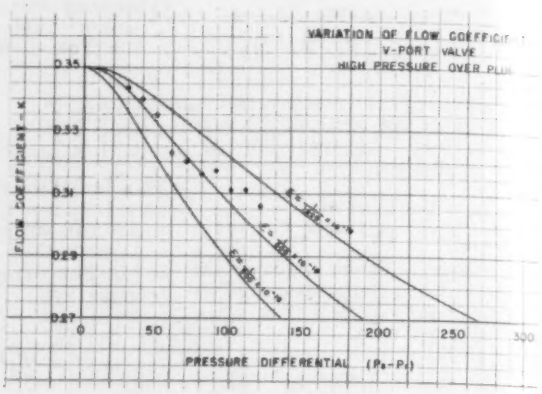

Fig. 6

The variation of flow coefficient with pressure drop is given by,

$$(13)\quad \frac{2g\rho^2}{\mu^2}(P_2-P_1)=\frac{1}{\rho^6 C^3 \varepsilon^{1/2}}\left[\frac{1-\left(\frac{K}{C}\right)^2}{\left(\frac{K}{C}\right)^6}\right]^{\frac{1}{2}}$$

The flow coefficient equation (13) is plotted together with the data in Fig. 6 for high pressure over the plug. The ideal flow coefficient (C) is here taken as 0.35. The agreement between the equation and the tests may be considered reasonable at a loss coefficient of approximately

$$\epsilon = 1.2 \times 10^{-21}$$

Note that the flow coefficient ordinate (vertical) is considerably expanded so that the usual randomness noticeable in all hydraulic data is accentuated. The important fact is that the theoretical equation illustrates the actual trend in flow coefficient at changing pressure differentials.

The flow coefficient equation is plotted together with the data in Fig. 7 for high pressure under the plug. The ideal flow coefficient is here taken as 0.316. The loss coefficient (ϵ) is seen to be about 0.5×10^{-21} and the agreement of theory and fact is inspiring. Note that the loss coefficient (ϵ) is very "sensitive" to the powerful effects of entrance and exit passage construction. The ratio of loss coefficients for forward and reverse flow is greater than 2 to 1 whereas the flow coefficients differ by only about 10 percent.

The principal fact afforded by this comparison is that the variation of flow coefficients even for moderate pressure differentials is too large to be ignored. Furthermore, the difference in flow coefficient for forward and reverse flow may be too large to be ignored.

Factors Influencing Valve Selection

In considering the flow through control valves there are several influencing factors apparent from a study of the flow coefficient equation. Consider that a valve is desired to operate under any reasonable values of pressure differentials and flow rates.

First, it is apparent that the calculation of valve flow cannot be based upon extrapolation of data taken at one pressure differential only and extrapolation of valve flow to higher pressure differentials may be seriously in error. Adequate corrections must be included for the variation in flow coefficient and for the effect of pressure losses.

As a matter of fact even the common assumption that the flow coefficient of a valve is the same for both forward and reverse flow is proved to be in error.

Second, the selection of area of valve ports (A) should be dependent not only on the pressure differential and flow rate but also upon the area coefficient (β). It therefore appears logical to proportion the maximum port area of a control valve to correspond to the pressure differential with which it is used. Only in this way can a reasonably consistent calibration of flow versus valve position be obtained.

The flow coefficient equation (13) demonstrates that the magnitude of flow coefficient depends upon the following factors:

pressure differential (P_2-P_1)
nominal entrance area (E)
Area coefficient (β)
ideal flow coefficient (C)
loss coefficient (ϵ)

in addition to the fluid characteristics such as density and viscosity! However, it is especially important that the ratio of valve port area to nominal entrance area ($\beta 2$) be decreased as the pressure differential increases so as to maintain the same variation in flow coefficient at all valve openings.

Third, the area of valve ports (A) should be considerably less than the valve entrance area (E) so that the area coefficient (β) is much less than one. The effect of head losses can be greatly reduced in the same manner as a decrease in loss coefficient (ϵ) reduces head losses. The valve can then be made to operate with satisfactory flow characteristics over a greater flow range since the pressure differential at the port opening is more nearly constant.

It is readily apparent that a control valve should be designed to operate at a specified non-minimum differential because the flow coefficient must be maintained constant through selection of a low area ratio. This is the main characteristic differentiating the control (throttling valve) from a hand valve.

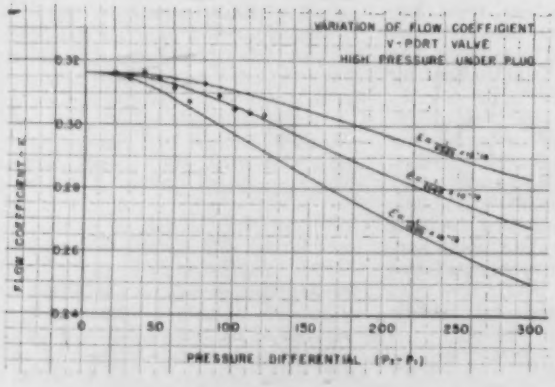

Fig. 7

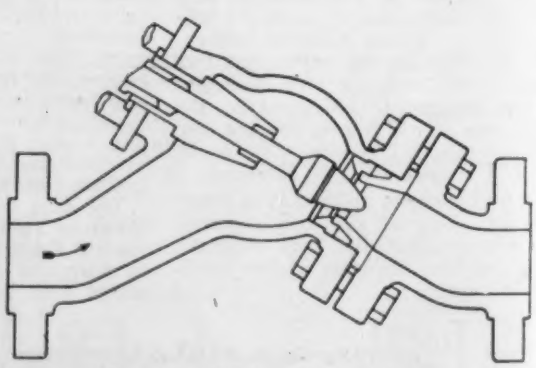

Fig. 8. Streamlined control valve body.

Fourth, the design of the valve must be such as to reduce the pressure losses to a minimum. This can generally be accomplished by leading the flow stream to the valve ports with gradually reducing sections (cones) having the smallest possible change in direction. The flow stream should be non-rotational, that is, have no vortices. The flow stream should not impinge on itself as in most open-skirt valve and double-ported valves since this introduces additional turbulance pressure loss. In fact, a control valve similar to that sketched in Fig. 8 is probably the nearest practical approach to the ideal.

SUMMARY

The problem of fluid flow through a control valve is not a simple one and is not a problem which yields readily to rigorous analysis, if at all. Reliance must be placed upon flow data at operating conditions. The data cannot be safely extrapolated at high differentials.

It is evident that the double-ported balance valve and even the conventional single-seated globe pattern leaves much to be desired when it comes to head losses. It is evident also that desirable flow characteristics cannot be expected in a given valve operating at high differentials just because these characteristics were obtained at low differentials. More thought should be given to streamlined body design, using single-seated valve plugs; this entails more thought on motor design.

It is sincerely hoped that this discussion will open the way toward further analysis and stimulate more thinking on this subject of so much importance to automatic control.

REFERENCES

1. Rouse, H., "Elementary Mechanics of Fluids," John Wiley & Sons, Inc., New York, 1946

2. Prandtl, L., and O. G. Tietjens, "Applied Hydro- and Aeromechanics," 1934 McGraw-Hill Book Co., Inc., New York, 1934.

3. Peters, J. C., "Getting the Most Out of Automatic Control," *Industrial and Engineering Chemistry*," Vol. 33, 1941, page 1095.

4. Pigott, R. J. S., "The Flow of Fluids in Closed Conduits," *Mechanical Engineering*, Vol. 55, 1933, page 497.

(Continued from Page 268)

was illustrated with slides and stressed the difficulties which occur in regulators operating under very high differential pressures.

The next meeting will be held on March 7, and the speaker will be Mr. Alexander Thackera of the Mason-Neilan Co. He will discuss the four general types of liquid level control and some problems encountered in the field with them. The talk will be preceded by a dinner at the Army and Navy Club. —C. G. FELLOWS, Vice President.

CHICAGO

All attendance records for Chicago Section meetings were broken on Feb. 7th when over 300 members and guests assembled at a non-dinner meeting in the Peoples Gas Light and Coke Co. auditorium to enjoy the "double feature" evening. This was a joint meeting of the Chicago, South Bend and Northern Indiana Sections, with special invitations to the Chicago Sections of the ASME, ACS, AICHE, and other engineering societies.

Technical Chairman J. B. McMahon opened the technical session by introducing Al Sperry, who presented a brief "Report of the ISA Recommended Practices Committee." Al explained that in the short span of two years, this committee has solicited and amassed enormous quantities of information upon which tentative recommended practices have been prepared or are in the process of preparation. Operating through more than a dozen sub-committees, the committee has proceeded cautiously but steadily, and has just released the reports of sub-committees EP-1 and RP-2, covering respectively the "Coding of Thermocouple and Lead Wire" and "Manometer Tables" recommendations. Another sub-committee, RP-3, has its recommendations on "Flowmeter Installation and Seal Pots" ready to go to press, and two or three others will be ready for preliminary release soon. Al also reported that a new sub-committee on recommended practices for "Instruments for Fractionating Towers" has recently been set up, with Chicago Section's Dave Boyd (Universal Oil Products Co.) as Chairman.

The second feature was the "Automatic Control Demonstration" and lecture by R. N. Pond, assisted by Mr. R. Brostedt, both of Taylor Instrument Co., Rochester, New York. This demonstration, which has gained nation-wide fame and popularity through its numerous presentations, held the audience enthralled for over two hours, and brought out the basic principles of automatic control by pneumatic instruments.

Starting with a "fairy tale" of two partners who wanted to convert their batch chemical process to a continuous process, Mr Pond brought out the various problems and their solutions, together with the reasoning behind each change made in the instrumentation of the process. After he had the partners "living hapoily ever after," he and Mr. Brostedt unveiled the demonstration apparatus and actually demonstrated (by means of a liquid level process) the various types of control previously described. From on-off and proportioning control, through automatic reset and derivative (rate) response, each type of control was effectively pictured on a 30-inch strip chart recorder while load changes, lag, and other variables were set into the equipment by means of valves, tanks, etc.

The precision and flexibility of the demonstration equipment were exceeded only by Mr. Pond's excellent handling of this most interesting subject. The Chicago Section hereby tenders a most appreciative vote of thanks to Messrs. Pond and Brostedt and the Taylor Instrument Co. for their cooperation in making this meeting so successful. —R. R. PROCTOR.

EASTERN NEW YORK

The regular monthly meeting was held on Feb. 1st, at Siena College, Loudenville, N. Y. with 35 members and guests in attendance. Prececding the meeting a slide film with recorded lecture titled "Harnessing the Electron, Part II," was shown. This was the second film to be shown before the regular meeting and response was such that it will be continued as standard practice.

The meeting was called to order at 8:00 PM and after a short business session the speaker for the evening, Mr. Paul S. Dickey, Vice-President Bailey Meter Co. was introduced.

Mr. Dickey's subject was "Recent Developments in Automatic Control for Power and Process Industries." Mr. Dickey deviated slightly from his major theme by explaining the advancement of instrumentation from the first World War through to present-day production. He used slides showing the major divisions of the American scientific instrument industry and completed this talk with slides and theory on pneumatic process control.

The next regular meeting will be on March 1, 1949, Behr-Manning Co., Troy, N. Y.—"Theory & Maintenance of Pneumatic Valves." W. J. CLAFFIE, Corr.

GULF COAST

The regular monthly meeting was held Feb. 4th, at Lamar College, Beaumont, Texas. The meeting was moved up to this date in order to hear a talk given by Mr. Bruce A. Irvin, Vice President, Hammel-Dahl Co. Mr. Irwin's subject was "The Angle Valve," of which he gave the structure and characteristics, demonstrated with slides.

Mr. C. B. Moore, of the Moore Products Co., Philadelphia, Pa., is scheduled to be the speaker for the March meeting. This meeting is to be held at Lamar College, March 1, 1949. —J. W. RUTLEDGE, Corr.

HOUSTON

The Jan. 31st meeting had two points of special interest. The first of course, was the program. Bruce Irwin, of the Hammel-Dahl Co., discussed diaphragm motor valves, emphasizing the features of angle valves.

W. H. Fortney reported on the hopeful subject of the "1951 Convention in Houston." He is chairman of the committee which has investigated Houston's facilities for holding the 1951 ISA Convention. The hotels can easily handle the expected crowd. At least two places will be available with more than enough capacity for the instrument show and the meetings. One is the air-conditioned Coliseum within easy walking distance of the downtown hotels. The other is in the nearly completed center around Glenn McCarthy's Shamrock Hotel in the South End. The other requirement is an ISA Section to do the hard work involved in being host. The Houston Section has considered these bitter angles and is ready for them. We are pulling for a favorable vote at the ISA Directors' meeting next May. —J. A. PARKER, Corr.

KANSAS CITY

The Section held its regular meeting on Tuesday, January 25th at "The Crossroads." Guest speaker was Loren E. Oberhelman, Standard Oil Co., Sugar Creek, Mo., who presented a blackboard talk on "Practical Considerations of Level Control." He started with the most simple type of level control and developed this into the most refined type. His explanation of "hold up time" and the means of calculating the length of float, etc., were very ably presented.

Oliver Boutros, our ISA Delegate reported that there was still a good chance that the 1951 ISA Exhibit would be held in Kansas City. New members elected to the Council are as follows:
Loren E. Oberhelman,
Standard Oil Company,
Sugar Creek, Missouri.
Harold B. Stevens,
Colgate-Palmolive-Peet Co.,
Kansas City, Kansas.
George J. Willier,
Foxboro Company,
Kansas City, Mo.

Our guest speaker for the Feb. 22nd regular meeting was H. F. Barrett, Sales Manager, Buffalo Meter Company, Buffalo, New York. His subject was "What Can You Do With Displacement Meters For Measuring Liquid?" Mr. Barrett opened his talk with a statement which certainly bears recording and repeating. "These ISA meetings which are being held all over the country represent the American way of business. The open exchange of information which we have here could not happen in European countries." Mr. Barrett outlined and explained the various types of meters.

The largest number of meters made are of the Single Piston type which is further broken down into the three types: Rotary, Oscillating, and Nutating. Buffalo Meter Company makes the Nutating type so Mr. Barrett explained in detail the use of this type meter. Mr. Barrett ended his talk by showing a colored picture trip through the Buffalo Meter's plant at Buffalo, New York. —W. A. REICHOW, Corr.

MONTREAL

On January 31st the Montreal Section held its regular monthly meeting in the Canadian Legion Memorial Building, Montreal.

Mr. E. C. Bowen, Eastern District Manager of the National Technical Laboratories—makers of Beckman Equipment, was guest speaker. His talk on "pH Measurement and Control" covered the fundamentals of pH measurement, the equipment involved, and numerous industrial applications, which were well illustrated with slides.

Congratulations and best wishes of the Section were given to Douglas Zimmerman, who is taking charge of the Fischer and Porter Company Canadian headquarters in Toronto. Mr. Zimmerman was active in the original formation of the Montreal Section. —G. A. RICE, Corr.

NEW JERSEY

The February meeting held at the Essex House Newark, N. J., on Feb. 1st featured a talk by Mr. Ward Percy of United States Steel Corp. Mr. Percy covered in a most interesting fashion "Instrumentation Practices in the Steel Industry."

An added interest has been created at each monthly meeting by arranging for a one-table exhibit of equipment. The exhibitor is selected so that no interference with the speaker is created. The exhibit is used both before and after the technical program. This phase of the program has been ably handled by Professor Paul Creager of Rutgers University.

A report from Harry Moore, Chairman of the Educational Committee, indicates excellent progress. Approximately 55 students (two classes) are completing the first course which dealt with the basic physics of measurement and instrumentation. These classes have been held at the Newark College of Engineering, and have aroused such interest that plans have been made for a second semester course. This course will consist of material on the application of measuring equipment in the four main fields of temperature, pressure, flow and level. The first semester touched on application only when required to explain the basic physics of the instruments proper.

A primary problem in making the arrangements for the more difficult applications course has been to secure the services of a competent instructor, as a wide industrial background is considered essential. Because of the difficulty of obtaining acceptance by one man for the full term it is planned to have separate instructors for each of the four main classes of measurements. Three qualified men have thus far been selected.

The March 1st meeting will be held at the Essex House, Newark, at 8 PM. Information of especial interest to management as well as plant instrument department personnel will be presented by Mr. J. W. Graeb in his talk "Starting Up Process Units and What it Teaches the Instrument Engineer." He will cover the problems arising from various divisions of responsibility between the contractor and owner in the design and erection of a unit; the necessity for adequate inspection as the installation progresses; the need for full cooperation between the operating and instrument departments and how to determine the number of instrument men required during the start-up and the training they should receive.

An exceptional program is being planned for April 5th. Afternoon and evening sessions will be held in the Oxford-Cambridge Room of the Essex House. Four outstanding experts in the field of automatic control will strip the mystery from "Derivative Control Action." Speakers will be Messrs. V. V. Tivy, of the Foxboro Co., R. E. Clarridge, of Taylor Instrument Companies, L. E. Jewett of Leeds & Northrup Co., and C. B. Moore of Moore Products Co. During the cocktail hour following the afternoon session the Foxboro Company will provide equipment to demonstrate the practical application of this little understood control action. Members of other sections are especially invited to attend this meeting.

—W. A. HAGERBAUMER, Corr.

SYMPOSIUM ON DERIVATIVE CONTROL ACTION

What it is and how to use it intelligently.
Time: Tuesday April 5, 1949
Place: Oxford-Cambridge Room
Essex House Hotel
Newark, New Jersey

Afternoon Session—2.30 P.M.

An outstanding paper on the Derivative Function in Automatic Control will be delivered by Mr. V. V. Tivy, Manager of Refinery Sales for the Foxboro Company. Mr. Tivy will explain in simple terms just what Derivative (Rate) Action is; the function it performs in Automatic Control, and will illustrate how it can be used with several applications in Industry. Prepared Discussions of this paper will be given by Mr. R. Clarridge, Manager of Application Engineering Dept., Taylor Instrument Companies, and Mr. L. E. Jewett of Leeds and Northrup Company's Automatic Control Engineering Dept.

Social Hour—5 P.M.

During the Cocktail Hour following the Afternoon Session a Demonstration arranged by the Foxboro Co. will illustrate Derivative (Rate) Action.

Evening Session—8 P.M.

A contrasting phase of Rate Action in Automatic Control will be described by Mr. C. B. Moore, Senior Partner of Moore Products Co., who will present a paper on "Inverse Derivative."

NIAGARA FRONTIER

The regular monthly meeting was held on Jan. 24th at the New York State Institute of Arts and Sciences in Buffalo. The meeting was preceded by a dinner, held in the restaurant of the Institute, at which some 25 members were present.

A short business meeting began at 8 PM under the direction of President Clarence Boltz followed by a panel discussion on instrumentation in general presided over by executive Vice President Joseph Hildyard acting as technical chairman. The following meetings are sceduled to be held at the New York State Institute of Applied Arts and Sciences, 1685 Elmwood Ave., Buffalo, New York. Meetings will be started at 8 PM, preceded by a dinner at 6:30 PM at the same address.

Feb. 21st—Dr. W. N. Greer, Leeds and Northrup Co., "Electrochemical Measurements in Industrial Processes."

Mar. 28th—Mr. W. E. Rufleth, Application Engineer, The Bristol Co., "Telemetering."

Apr. 25th—Mr. Paul Elfors, Vice-Pres., Fisher Governor Co., "Diaphragm Motor Control Valves—Construction and Applications."

—W. J. SOMMERS, Corr.

OAK RIDGE

The Oak Ridge Section met Feb. 1st at The Oak Terrace, Oak Ridge, Tenn. Program committee chairman, Mr. Campbell, gave us an outline of the programs for April, May, and June.

Educational Chairman, George Jamieson, discussed the new Section paper which will be produced monthly. This paper will contain news regarding happenings within our Section, National Society Notes and Technical Articles. Also, Mr. Jamieson intends to organize two groups of members interested in gaining additional knowledge of "Electronic Principles". He will conduct one class for "Beginners" and the other for those who understand the fundamentals of basic electronics.

It was decided that our July Meeting would be at a location suitable for a picnic dinner. This was suggested because the weather is usually warm then and interest in our meetings is often declining because of this and vacations.

Membership Committee Chairman, Harold Shnider, announced that he hoped to have at least twenty new members before our March meeting date arrives. He has already submitted several applications for approval.

Our guest speaker, Mr. C. E. Mason, of the Bristol Co., gave a very interesting talk regarding "The Theory of Air Control". He used slides to supplement his talk.

Our March meeting will be at The Oak Terrace and Dr. Mouzon will discuss the "Vibrating Reed Electrometer".

—JOHN H. CLARK, Sec'y.

PHILADELPHIA

One hundred thirty members and guests attended the Jan. 19th meeting at the Bellevue-Stratford Hotel, President Alfred Krieg called the meeting to order at 8:00 PM. The Treasurer's report and the Education Committee's report comprised the routine business.

The speaker of the evening, Mr. O. W. Livingstone, Engineer of the Electronics and Regulator division of the General Electric Co., Schenectady, N. Y., presented a very interesting and informative discussion on the basic principles of Thy-Mo-Trol, Electronic Amplidyne and Reactrol Systems of Control. These units all depend upon extensive use of vacuum tubes to which the speaker has devoted more than ten years of research and development.

Thy-Mo-Trol is a device used for controlling the speed of a DC motor from an AC supply through the medium of vacuum tubes. It provides a wide range of adjustment and maintains motor speed at any desired rate. It may be used on motors in sizes ranging from 20 HP to fractional HP. The Electronic Amplidyne essentially consists of a special DC generator equipped with a control winding and an additional set of brushes which are short circuited. It is so arranged with an amplifier that small changes in the control field winding produce a large change in generator output. To overcome the drift problem, common to DC amplifiers, high voltages in the order of 100 volts are used to minimize percentage errors. This system is used on high speed applications where accurate control of current, voltage speed, etc. are required.

Reactrol is an electronic system which automatically regulates the power input to furnaces or ovens which are heated by resistance heating elements. It employs a saturable core reactor having both AC and DC windings. By varying in the DC winding, a small current usually obtained from electronic amplifiers, stepless control of large AC currents is provided.

—W. E. HARRISON, Corr.

PITTSBURGH

Forty members and guests gathered for dinner on Jan. 24th and sixty were present when the meeting opened. Included in a short business session was a brief report by Dick Rimbach on progress of the St. Louis Conference and Exhibit. Bill Kendig then introduced the speaker, Mr. R. C. Byers of Westinghouse Electric Corp. who spoke on "Quality Control and Instrumentation".

Mr. Byers explained how the quality control engineer utilizes the data furnished by inspection instruments and gages. From actual case histories he showed how statistical analysis applied to inspection data improved several manufactured products. While high class inspection instruments cost more than go-no-go gages, they soon pay off in the type of information furnished. Mr. Byers stated that 14 times as many go-no-go measurements are required, as quantitative measurements, to determine the quality of a group of objects. He asked instrument manufacturers to develop more sensitive instruments and gages.

The next meeting will be held in Pittsburgh on Feb. 28th. Dr. Harold T. Clark, Assistant Director of Research of Jones & Laughlin Steel Corp., will speak on "Temperature Measurement of Open Hearth Bath".

—MARVIN M. FROMM, Corr.

SAINT LOUIS

The regular meeting was held on Feb. 2nd at the Engineers' Club in St. Louis. Prior to the talk, Mr. Phil Watson, Chairman of the 1949 Conference and Exhibit, outlined progress made thus far in preparations for the Conference to be held in St. Louis September 12 to 16, 1949.

Speaker of the evening was Mr. M. H. Strickland of "Proportioneers, Inc." who spoke on "Proportioning Devices". Mr. Strickland outlined a method of proportioning in which the materials are proportioned by measuring the loss of weight of the tank (or hopper) from which the materials are fed. Proportional rates of feeding or several materials are insured by operating a master Selsyn motor at variable speed depending on the output desired. The master Selsyn operates a slave Selsyn in each scale mechanism which operates a lead screw that moves a weight along the beam. The beam carries control devices that cause material to be fed to keep the scale in continuous balance.

Mr. Strickland also described a method of control in proportioning in which a flexible shaft operated by the register of a displacement type meter is fed into one gear of a differential unit, the other gear of which is attached to a material feeding mechanism. The spider of the differential unit operates a control system which acts to keep the feeder in step with the meter rotation, in which case there is no deflection of the spider. In this way very accurate proportioning can be obtained. Still another method of proportioning described was the use of variable stroke, displacement type pumps, in which the speed or stroke length are varied by control devices associated with meters or scales. This system may be used where the additive is small in quantity in comparison with the main flow.

—HENRY E. ZEFFREN, Corr.

SOUTH TEXAS

The South Texas Section met on Feb. 1st, in the Taylor Refining Co.'s recreation Hall in Corpus Christi.

A large attendance of members and visitors was present to hear an interesting discussion by Mr. Bruce Irwin, Vice President, on developments in control valves. He gave us detailed information on early types of valves and the new angle valve, with emphasis on the quietness of operation, high "rangeability", and durability.

—L. NEEDHAM, Corr.

TENNESSEE

The Tennessee Section held its regular meeting on Jan. 11th. After a short business session the guest speaker, Mr. Frank S. Ward, Sales Manager, Industrial Div., Taylor Instrument Companies, was introduced. Mr. Ward presented a rather unique talk entitled "A View of Industrial Instrumentation from a Different Angle" in which he took his audience on a behind-the-scene tour of what goes on in the sales division of a large instrument company. The necessity of forecasting the volume of sales eighteen months in advance on each type of instrument in the company's line and placing orders for materials based on this estimate leaves no doubt as to the responsibility of the sales organization. Based on this sales estimate, Mr. Ward went on to explain how this affected deliveries and the introduction of new lines of equipment.

Following the talk, a discussion period was held. One topic of much discussion was a comparison of the relative merits of the bulb and tube system type of temperature measurement against the potentiometer

SECTION SECRETARIES AND MEETING DATA

	Telephone	Date	Dinner	Meeting
Akron: Fred Appel, 932 Columbia Ct., Barberton, Ohio.				
Aruba: A. S. MacNutt, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.		1 Tues.	X	7:15
Atlanta: R. E. Fishburn, Minneapolis-Honeywell Reg. Co., #5 Rhodes Center, N. E. Atlanta, Ga.		4 Mon.		
Baltimore: Felix Cox, Bethlehem Steel Co., Sparrows Point, Md.		2 Fri.		
Boston: C. J. Nazzaro, 456 Central Avenue, Milton 87, Mass.		Last Wed.	6:00	7:00
California: D. D. Taylor, 234 E. Colorado, Pasadena 1, Calif.		1 Tues.	6:30	
Central Illinois: T. A. Carroll, 721 Hurlburt St., Peoria, Ill.		1 Wed.	6:30	7:30
Central Indiana: H. F. Coffey, 110 G Nelson Ave. Tyndall Towne, Indianapolis, Ind.		1 Tues.	X	7:30
Charleston: Albert H. Hix, 1529 B Dixie St., Charleston 1. W. Va.		1 Mon.	X	8:00
Chicago: Floyd E. Erstman, 506 S. Wabash Avenue, Rm. 611, Chicago 5, Ill.		1 Mon.	6:30	8:00
Cincinnati: Smith Hickenlooper, 1147 Beverly Hills Dr., Cincinnati, Ohio.		4 Mon.		
Cleveland: L. H. Waldrip, 3030 Euclid Ave., Cleveland, Ohio.		4 Wed.	6:30	8:00
Cumberland: Clyde Babst, P. O. Box 447, Cumberland, Md.		*Tues. after 4 Mon.*	6:30	8:00
Detroit: T. S. Cawthorne, 570 Maccabees Bldg., Detroit 2, Mich.		3 Tues.		
Eastern New York: Wm. J. Claffie, Winthrop-Stearns, Inc., 33 Riverside Ave., Rensselaer. N. Y.		1 Tues.	6:30	8:00
Gulf Coast: A. E. Bunn, 2237 North Street, Beaumont, Texas.		3 Tues.		
Houston: E. E. Kleir, 2518 S. Blvd., Houston 6, Texas.		Last Mon.	X	8:00
Inyokern, China Lake, Calif: Arthur G. De Bell, 1208 Micholson Lab, China Lake, Calif.				
Kansas City: Lewell F. Spies, J. F. Pritchard & Co., 908 Grand Ave., Kansas City, Mo.		Last Tues.	6:30	7:30
Louisville: H. C. Scherffius, 980 Palatka Rd., Louisville, Ky.		4 Tues.	X	8:00
Montreal: F. S. McCarthy, Canadian Industries, Ltd., Box 10, Montreal, Quebec, Canada.				
New Jersey: W. D. Archibald, 605 Westminster Ave., Elizabeth 3, N. J.		1 Tues.	6:00	
New Orleans: W. H. Haney, 2927 Music Avenue, New Orleans, La.		*No Regular Date*		8:00
New York: C. E. Haggerty, 7552 181st St., Flushing, L. I., N. Y.		Last Mon.	6:30	8:00
Niagara Frontier: K. J. Fees, RFD #1, Niagara Rd., Niagara Falls, N. Y.		4 Mon.	X	8:00
North Texas: F. Zapffe, Lone Star Gas Co., 2701 Logan St., Dallas 1, Texas				
Northern Indiana: C. P. Haynes, 935 177th Place, Hammond, Indiana.		3 Wed.	6:30	7:30
Oak Ridge: John H. Clark, 138 Clayton Hall, Oakridge, Tenn.		1 Wed.	7:00	
Ontario: A. J. Legault, Bristol Co. of Canada, Ltd., Toronto, Ontario, Canada.		3 Thur.	6:45	
Philadelphia: C. W. Wood, 6908 Market St., Upper Darby, Pa.		3 Wed.	X	8:00
Pittsburgh: L. M. Susany, c/o Carnegie Institute, 4400 Forbes St., Pittsburgh 13, Pa.		4 Mon.	6:30	8:00
Presque Isle: R. P. Marshall, 161 W. Main St., North East, Penna.		4 Tues.	X	8:00
Richland: R. S. Hammond, 402 Abbott, Richland, Washington.		2 Wed.	X	7:30
Rochester: R. C. Swartz, Jr., 1201 Granite Bldg., Rochester 4, New York.		3 Tues.	X	8:00
St. Louis: W. G. Lee, 4710 Delor St., St. Louis 16, Mo.		1 Wed.	X	8:00
Sarnia: C. G. Elder, 323 Maria St., Sarnia, Ont., Canada.		2nd & 4th Fri.	X	
South Bend: Charles E. Williams, 921 Lawndale Avenue, South Bend, Ind.		1 Thur.	6:30	7:30
South Michigan: Homer Kuiper, 2517 Hillsdale, Kalamazoo, Mich.		2 Wed.	6:30	8:00
South Texas: H. C. Givens, La Gloria Corp., P. O. 637 Falfurrias, Texas.		1 Tues.	X	7:30
Tennessee: L. W. Thayer, 1837 Oakwood Dr., Kingsport, Tenn.		*No Definite Night*	7:00	8:00
Tulsa: C. R. Horton, 8211 E. 7th, Tulsa, Oklahoma.		1 Mon.	X	7:30
Twin Cities: Ray Hooper, International Div. Minneapolis-Honeywell Reg. Co., 2753 Fourth Ave., Minneapolis 8, Minn.		4 Tues.	6:30	
Washington: Edwin G. Brown, c/o American Instrument Co., 8010-20 Georgia Avenue, Silver Spring, Md.		3 Mon.	X	7:30
Wayne County: R. L. Swenson, 1569 13th St., Wyandotte, Michigan.		3 Mon.	6:30	8:00

type. The majority of the audience was surprised to learn that means have been devised by which the bulb system could very nearly approach or better the response characteristic of the thermo-couple instrument. The meeting adjourned at 10:30 P.M.

—J. T. ELDER, Corr.

WASHINGTON

The annual dinner meeting was held Jan. 24th at the YWCA at 17th and K Streets, N. W. The meeting was the one set aside for entertaining the wives and other guests of the members, and was non-technical. The dinner was followed by a number of extemporaneous speeches on arbitrarily assigned subjects. The speakers had no warning prior to their selection by the Meeting's Chairman, Mr. R. E. Hightower. However, they all found inspiration and delivered talks which were more humorous than profound, and which were applauded freely.

Following the talks, Mr. Hightower showed several reels of non-classified motion pictures of Naval Ordnance being given field tests by Naval Ordnance Laboratory of White Oak, Maryland. Included in the pictures were a large number showing mines being dropped from planes. These proved of particular interest to the audience.

—RAYMOND E. MILLER, Corr.

ISA EMPLOYMENT SERVICE

Forward your letter to INSTRUMENT SOCIETY OF AMERICA, 1117 Wolfendale St., Pittsburgh 12, Pa.

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R-119 TRANSFORMER RATIO MEASUREMENT. 8-page Bulletin 55 describes and illustrates maker's instrument for measuring turn ratio in power transformers. Also checks polarity, tap changer defects, and problems of load division and circulating currents. Principle and method of operation discussed.—James G. Biddle Co., 1316 Arch St., Philadelphia 7, Penna.

R-120 SLIDE WIRE RESISTANCE BOXES. 2-page bulletin describes and illustrates maker's "Type 110-A" slide wire resistance boxes designed for student and general laboratory use as a practical substitute for decade resistance boxes. Features and specifications are discussed.—Technology Instrument Corp., 1058 Main St., Waltham 54, Mass.

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R-122 SOLDERING MANUAL. 28-page technical manual entitled "Solder and Soldering Technique" gives analysis of properties and application of soft solder alloys and soldering fluxes.—Kester Solder Co., Technical Dept., 4201 Wrightwood Ave., Chicago 39, Ill.

R-123 MEASUREMENT AND CONTROL INSTRUMENTS. 44-page Catalog ND46(I) describes and illustrates maker's complete line of "Speedomax" instruments, indicators, indicating recorders, recording controllers, etc. Catalog lists uses for which instruments are available. Illustrations include design features, schematic diagrams, sections of round and strip charts.—Leeds & Northrup Co., 4934 Stenton Ave., Philadelphia 44, Penna.

R-124 SELENIUM RECTIFIER DATA. 20-page booklet is designed to aid users of rectifiers to select, buy, and use them properly. Subjects discussed are: cell sizes and ratings, construction, protective coatings, grading of cells, efficiency, circuit formulae and constants, etc. Illustrations are used throughout. — Fansteel Metallurgical Corp., Rectifier Div., North Chicago, Ill.

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R-126 CAPACITOR ENCYCLOPEDIA. 56-page Encyclopedia No. 163 is said to be largest, most complete encyclopedia for capacitors used in capacitor type motors ever issued. Provides interchangeability tables with instant selector indices. Also includes replacement tables—listing proper C-D type for replacing units made by other companies. Sections cover: motor parts No. (alphabetical and numerical), cross index of C-D replacements, etc.—Jobber Div. Cornell-Dubilier Electric Corp., South Plainfield, N. J.

R-127 DYNAMOMETERS. 4-page Bulletin D illustrates and describes many uses of maker's dynamometer for measuring traction, tension or weight. Construction and features are discussed.—W. C. Dillon & Co., Inc., 5410 W. Harrison St., Chicago 44, Ill.

R-128 MOISTURE TESTER. 4-page Bulletin AL-34 describes and illustrates maker's "Speedy" moisture tester for determining moisture content of sands, clays, tobacco, grain, etc. This control instrument for substances during process is independent of electricity and graphs, requires no special set-up, may be worked in conjunction with sand cutters, etc. Unaffected by vibration or being set off level. Instructions for use are included.—Alpha-Lux Co., Inc., 155 John St., New York 7, N. Y.

R-129 SOLDERING TOOL. 4-page bulletin illustrates and describes maker's "Pres-To-Heat" soldering tool which is designed for rapid, precision soldering. Applications, design, features and construction are discussed.—Appliance Div., The Housing Foundation Inc., Deep River, Conn.

R-130 COLOR DENSITOMETER. 8-page folder describes and illustrates maker's color densitometer for use in fields of photography,

...ro-Chlor" dry vacuum chlorine dispensing ...s. Features, construction, operation, etc., are ...ussed.—Fischer & Porter Co., Hatboro, Penna.

...-146 INTERNAL COMPARATORS. 8-page ...letin No. 40 describes and illustrates maker's ...ntroplug" internal comparator production ...d inspection gage. Features, use, and other ...ns are discussed.—Comptor Co., 87 Rumford ..., Waltham 54, Mass.

...-147 SURFACE COMPARATORS. 4-page ...letin No. 32-A describes and illustrates maker's ...odel No. 6" quick scanning surface comparator ... production line inspection. Features, construc...n, etc., are discussed.—Comptor Co., 87 Rum...d Ave., Waltham 54, Mass.

...-148 AERATOR SYSTEMS. 4-page pocket ...e folder illustrates and describes maker's "Bin-...r" aerating device to provide uniform and steady ...w of bulk materials from bins, hoppers, and ...utes. Principle of operation and model specifica...ns are discussed. — Bin-Dictator Co., 14615 ...fferson Ave., Detroit 15, Mich.

...-149 VACUUM TUBE VOLTMETERS. 2-...e bulletin illustrates and describes maker's ...lti-purpose vacuum tube voltmeter and d-c. ...cuum tube millivoltmeter. Specifications, appli...ions, and features are listed.—Millivac Instru...nts, P. O. Box 3027, New Haven, Conn.

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...-154 RELAYS. 24-page Catalog No. 149 ...illustrates and describes maker's line of fifteen ...asic models of general purpose appliance, motor ...starting, and telephone type relays from which ...over 7000 different specifications have been ac...complished.—Potter & Brumfield Sales Co., 549 ...West Washington Blvd., Chicago 6, Ill.

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R-160 MEGOHMER INSULATION TESTER. 4-page Bulletin No. 455 illustrates and describes maker's new "Standard" megohmer insulation testers. Features include: constant pressure, slip-clutch d.c. generators, true cross coil ohmmeter movements with cobalt magnets, etc.—Herman H. Sticht Co., Inc., 27 Park Place, New York, N. Y.

R-161 HIGH VACUUM APPARATUS. 52-page Bulletin 10 describes and illustrates maker's vacuum pumps and accessories. Gives additional information on high vacuum system planning, pumping speed, low pressure techniques, gages, traps, cements and waxes, etc.—Central Scientific Co., 1700 Irving Park Road, Chicago 13, Ill.

R-162 EXTERNAL GAGING. 4-page bulletin describes and illustrates maker's "Series M Comtorgage" for precision external gaging of cylindrical work. Advantages, applications, models, sizes and prices are discussed.—Comtor Co., 76 Rumford Ave., Waltham, Mass.

R-163 MULTIPLE UNIT SIGNALS. 12-page bulletin describes and illustrates maker's "Series 300 Panalarms", a multiple unit signal that permits a single horn to serve for many alarms. When horn sounds, set of red and white lamps light up to indicate where trouble is.—Panalarm Products, Inc., 7216 North Clark St., Chicago 26, Ill.

R-164 VIBRATION FATIGUE TEST EQUIPMENT. 4-page Bulletin 310, describes and illustrates maker's "Model 10 VA" vibration fatigue testing machine which provides vertical vibration. Also discusses "Model 10 HA" which provides vibration horizontally. Specifications given, and testing machines for other requirements discussed.—All American Tool & Mfg. Co., 10104 Fullerton Ave., Chicago 14, Ill.

R-165 BASELINER. 4-page Bulletin describes and illustrates maker's "Model G-1402" baseliner which provides continuous reference of zero input voltage on a cathode-ray oscilloscope screen. Applications, theory of operation, and technical specifications included.—Globe Products Inc., 870 Maplewood Ave., Bridgeport 5, Conn.

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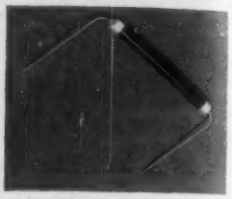

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